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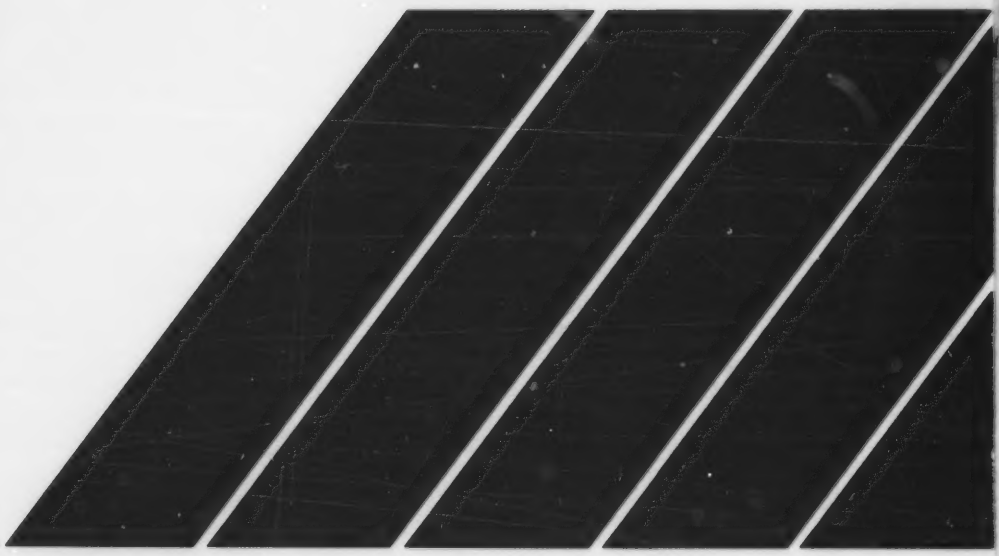
INDOOR FUELLING AND SERVICING OF METHANOL TRANSIT BUSES AT WINNIPEG TRANSIT



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INDOOR FUELLING AND SERVICING OF METHANOL TRANSIT BUSES AT WINNIPEG TRANSIT

PREPARED FOR:

Efficiency and Alternative Energy Technology Branch
Energy, Mines and Resources Canada
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EXECUTIVE SUMMARY

One potential barrier that may hinder wide scale acceptance of methanol in Canadian transit operations is refuelling, storage and maintenance of a fleet of methanol powered buses.

Canadian climatic conditions favour that almost all transit fleets perform these activities indoors. Winnipeg Transit Osborne Street bus garage was reviewed within the context of converting existing facilities to accommodate methanol fuel operations. Transit operation within the context of this report is limited to indoor service (refuelling and cleaning), storage and maintenance of transit vehicles.

The following report comprises a risk analysis of indoor operations on methanol fuel. More specifically, this report examines the following: individual fuel properties of methanol as compared with conventional transportation fuels; incident data within the transit industry; the current regulatory framework within Canada; and a risk management plan applicable to Winnipeg Transit. The study proposes measures to make indoor methanol operations comparable in safety with diesel.

Pertinent regulations applicable to transit operation in the Province of Manitoba and Ontario have evolved around the premise of using either flammable (gasoline) or combustible (diesel) liquids. Methanol is classified as a flammable liquid. There are no specific regulatory barriers preventing indoor operations with methanol fuel, however, there are certain ambiguities concerning its treatment. Furthermore, it appears that ultimate approval for an indoor facility rests with local fire safety authorities.

Present experience with methanol is limited to small scale demonstration programs with vehicle fuelling occurring outdoors. Any proposed methanol transit service must be evaluated against the existing regulatory framework as well as all specific concerns raised by transit operators and their insurers. Many of the concerns of transit operators can be identified through incident data revealing likely hazard precursors.

The major modifications proposed for Winnipeg Transit's Osborne Street facility include a sealed heating system, explosion-proof electrical componentry and spill containment tanks to prevent any spilled methanol from entering the sewage system. The total cost for all modifications at the Osborne Street facility is estimated to range between $900,000 and $1.5

million. The range in costs is due to some uncertainty with regards to the regulatory treatment of methanol, particularly the need for separate fuel catchment tanks. The estimate represents capital costs for hardware and employee training. It excludes incremental operating costs and any costs associated with vehicles. The vehicle service area requires the most extensive modifications, expected to amount to about $750,000.

Explosion proof electrical systems, sealed heating systems, and spill containment tanks would be required at other transit properties in Canada. The costs of these systems will be dependent on the facilities already in place. The costs would probably be less for constructing new facilities than for converting existing buildings and equipment.

Proposed modifications of the transit facilities, as described in this report, will not in itself satisfy regulatory authorities. Final confirmation as to the validity of the proposal can only be established once regulatory approval has been achieved. The process of realizing regulatory approval can be considered an additional design cost for a facility. Until a precedent for a methanol facility has been established, these costs could be significant.

RÉSUMÉ

Un des facteurs qui pourraient empêcher l'usage du méthanol de se répandre dans les services canadiens de transport en commun est lié au ravitaillement en carburant, à l'entreposage et à l'entretien de parcs d'autobus fonctionnant au méthanol.

En effet, en raison du climat canadien, ces opérations sont la plupart du temps effectuées dans des garages. On a donc décidé de déterminer les mesures que le service de transport en commun de Winnipeg devrait prendre pour pouvoir utiliser du méthanol dans ses installations de la rue Osborne. Dans ce rapport, il est question uniquement des opérations de ravitaillement en carburant, de nettoyage, d'entreposage et d'entretien des véhicules qui sont effectuées à l'intérieur des garages des services de transport.

Le rapport comprend une analyse des risques liés à l'utilisation de méthanol dans des aires intérieures. On y examine en particulier les propriétés du méthanol comparativement à celles des carburants classiques, les données sur les incidents survenus dans l'industrie du transport en commun ainsi que la réglementation au place au pays; on y propose également un plan de gestion des risques applicable au service de transport de Winnipeg. L'étude propose en outre des mesures visant à rendre l'utilisation du méthanol dans des garages aussi sécuritaire que celle du diesel.

Les règlements applicables au transport en commun dans les provinces de l'Ontario et du Manitoba ont été établis en fonction de l'utilisation de liquides combustibles (diesel) ou inflammables (essence). Le méthanol est classé dans cette dernière catégorie, et aucun règlement particulier n'en interdit l'usage dans des espaces intérieurs. Certaines ambiguïtés subsistent, toutefois, dans le traitement réglementaire de cette substance. De plus, il semble qu'en matière d'installations intérieures, la décision finale appartient aux services d'incendie locaux.

Jusqu'à maintenant, on a utilisé le méthanol uniquement dans le cadre de programmes de démonstration à petite échelle, où le ravitaillement des véhicules était toujours effectué en plein air. Les projets de création de services d'autobus fonctionnant au méthanol doivent être évalués à la lumière du cadre réglementaire en place et des préoccupations exprimées par les dirigeants des services de transport en commun et leurs assureurs. Les inquiétudes des services de transport en commun sont souvent liées à des incidents qui démontrent l'existence de certains risques relatifs à l'utilisation du méthanol.

Parmi les principales modifications que les auteurs du rapport proposent d'apporter aux installations de la rue Osborne, figurent l'installation d'un circuit de chauffage scellé, la mise en place de composants électriques antidéflagrants et l'utilisation de réservoirs de confinement destinés à empêcher le méthanol, dans le cas d'une fuite, de s'infiltrer dans le système d'égouts. Le coût total de ces modifications se situerait, pour les installations de la rue Osborne, entre 900 000 et
1 500 000 $. Cet écart s'explique par les ambiguïtés de la réglementation du méthanol, particulièrement en ce qui a trait à l'obligation de disposer de réservoirs séparés de réception du carburant. L'estimation tient compte des dépenses en capital liés à l'achat du matériel ainsi que du coût de formation des employés; elle exclut les frais d'exploitation différentiels et les coûts associés aux véhicules. Les modifications les plus importantes, qui entraîneront des dépenses d'environ 750 000 $, devront être effectuées dans l'aire d'entretien des véhicules.

Il faudrait mettre en place des systèmes électriques antidéflagrants, des circuits de chauffage scellés et des réservoirs de confinement dans des installations appartenant à d'autres services canadiens de transport en commun. Le coût de ces modifications varierait en fonction du type d'installation. La construction de nouveaux garages s'avérerait probablement moins coûteuse que la conversion de bâtiments et d'équipement existants.

Les modifications proposées dans ce rapport ne suffiront pas à satisfaire aux exigences des organismes de réglementation. Pour recevoir le feu vert, le projet devra être soumis à un processus d'approbation réglementaire, qui pourrait être considéré comme un élément de coût supplémentaire. Tant qu'un précédent n'aura pas été créé dans ce domaine, ces coûts pourraient atteindre des niveaux considérables.

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I INTRODUCTION

A. BACKGROUND

Urban transit buses constitute a highly visible sector of the motor vehicle fleet, which is often associated with urban air pollution. In response, engine manufacturers and transit fleets have begun to develop methanol as an alternative fuel. Methanol offers an opportunity to reduce regulated exhaust gases compared with diesel engines. However, before a transit fleet can consider the conversion of its entire fleet to methanol, many questions must be answered to ensure that all technical, social and legal barriers are overcome.

One potential barrier hindering wide acceptance of methanol fuel is the question of refuelling, storage and maintenance of a fleet of methanol vehicles. Most Canadian transit fleets perform these activities indoors due to climatic conditions. For methanol, the transit facility will have to satisfy regulatory constraints set by the local Fire Marshall and Provincial licensing boards as well as gain general acceptance by fleet personnel and the general public. Diesel fuel has been in widespread use throughout the transit industry for over 30 years. Over that time, certain attitudes towards fuel handling have evolved. Therefore, a thorough understanding of the risks involved with methanol fuel and ways to manage the risk at the transit facility must be investigated.

B. OBJECTIVES

This study examines the issue of methanol vehicle refuelling, storage and maintenance from the perspective of a transit fleet. The specific objectives of this study are to:

(a) Identify the risks involved with indoor fuelling, service and storage of methanol powered transit buses;

(b) Identify and address regulations applicable to indoor fuelling, service and storage;

(c) Present various approaches that may permit indoor fuelling, service and storage of methanol powered buses at the Winnipeg Transit Osborne Street facility. These approaches will be accompanied by an estimate of the magnitude of costs required to perform the suggested modifications; and

(d) Draw conclusions about the feasibility of indoor fuelling, storage and maintenance of transit vehicles based on findings at Winnipeg Transit and knowledge of transit operations in Canada.

This report does not examine any implementation strategies nor timetables to initiate the transition from diesel to methanol. The study only examines the transit facility and its operating procedures and makes a series of recommendations aimed at mitigating risk associated with methanol fuel at a transit facility.

C. METHODOLOGY

This report examines the relative risk that methanol buses pose compared with diesel powered transit buses. As humans, we tend not to judge things in absolute terms, but rather in relative terms, in other words, what is the probability of an event compared with some other event. The scope of this report is limited to an examination of vehicles while on transit property during the service, storage and maintenance functions. The ensuing risk analysis highlights which infrastructure and vehicle components, as well as operating procedures, should be upgraded or modified to account for the difference in fuel properties. By way of illustrative example, the Winnipeg Transit Osborne Street Facility (also referred to as the Fort Rouge Transit Facility) is cited. Winnipeg Transit has been an early and active participant in methanol engine technology development. Under the MILE (Methanol In Large Engine) Program, the City of Winnipeg has been operating two methanol fuelled transit buses since 1986.

The risk assessment phase of the study consists of identifying and evaluating different events (also referred to as hazard precursors) that can occur on a transit property.

There is currently limited data available that details "events" (e.g., vehicle fire) that have transpired on Winnipeg Transit property or other transit properties. Many events, such as transit vehicle fires, are so infrequent that one cannot confidently assign a statistical probability to their occurrence. Conversely, other events, such as a fuel spillage during refuelling, may be considered routine and as such no one takes notice or there is a reluctance to report the event. Due to the limited availability of hard data, the report used a comparative risk assessment approach. A qualitative examination of methanol, diesel and gasoline properties was used to identify how methanol will likely react compared to the two mainstream transportation fuels.

A survey of the Osborne Street Garage was undertaken to provide basic information on the site layout, number of vehicles stored and serviced, and desired performance standards. The survey also afforded the opportunity to observe refuelling and servicing procedures employed by Winnipeg Transit and to collect information on potential hazard precursors. Due to limited data detailing past incidents, we conducted a series of telephone interviews with other Canadian and American transit bus operators including OC Transpo (Ottawa), Toronto Transit and Seattle Transit, as well as the California Energy Commission, which have experience servicing and repairing methanol vehicles indoors. Most of the data collected was anecdotal, but can be considered a valid source of information in risk analysis.

The regulatory review contained in Chapter V identifies the relevant sections of legislation that are applicable to a Winnipeg installation. Many of the rules will also be applicable in other jurisdictions.

The risk management portion of the study addresses areas where methanol is considered a greater risk than either gasoline or diesel. A number of risk management strategies are promulgated along with an estimate of the magnitude of costs in order to evaluate the feasibility of the different strategies.

II TYPICAL SERVICING, STORAGE AND MAINTENANCE PRACTICES

A. INTRODUCTION

The following chapter presents an overview of typical transit vehicle operations. Transit vehicle operations of concern in this study are vehicle service, storage and maintenance. An understanding of these operations assists with the identification and evaluation of the risks associated with a particular fuel. The Winnipeg Transit Osborne Street Facility is used as a working example. Many of the practices and equipment employed at Winnipeg are, by extension, applicable at other transit facilities.

The Osborne Street Transit Facility, also known as the Fort Rouge Transit Facility, serves as the head office and main operating facility for Winnipeg Transit. The transit base was opened on November 20, 1969 and is presently operating at its design capacity of 330 buses. The overall facility is spread between two buildings; the repair shop and administration section are contained in one building while vehicle storage and service are located in an adjacent building. Figure II-1 presents a layout of the property. There is little remaining area on the property. The wedge shaped property is bound by railway tracks to the north and west, Brandon Street to the south and Osborne Street to the east. There is also a 3 storey apartment building located within the southeast corner of these boundaries. Vehicles enter and exit the property via Glasgow Ave. Winnipeg Transit also maintains two other facilities, the St. James and the Carruthers Garages, which are used to store, service, inspect and perform minor running repairs on vehicles.

B. VEHICLE SERVICE

Vehicle servicing consists of a fluid level check, tire pressure check, refuelling, internal bus cleaning and an exterior bus wash. The bus service bay is located along the west wall of the storage garage and operates continuously, year round.

Service crew members pick up vehicles from storage bays 2 and 3, and shuttle them through either lane of the service bay. The service operation is a continuous flow operation; vehicles enter at the south and exit from the north door. All vehicles must be refuelled and cleaned (interior andexterior).

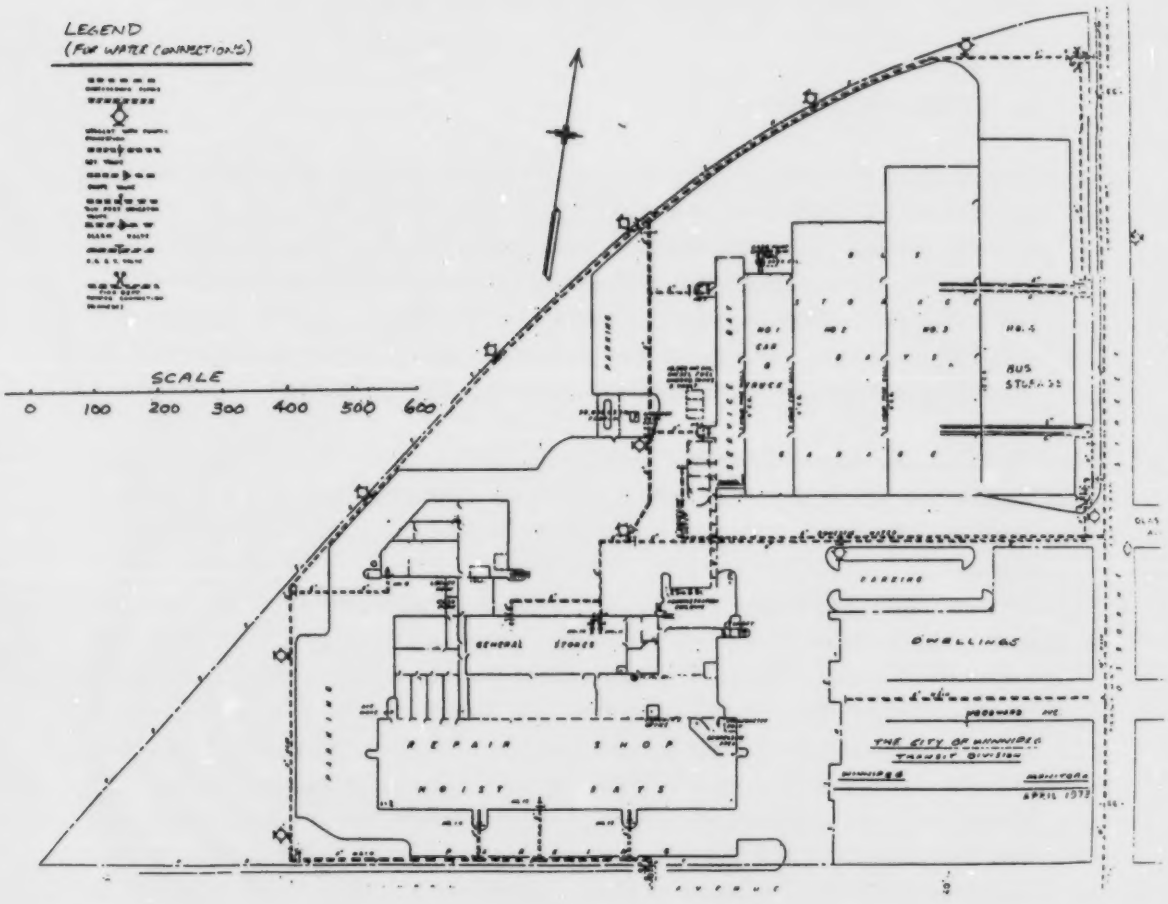

Figure II-1. Winnipeg Transit: Osborne Street Transit Facility Layout

Figure II-2 presents a layout of the service bay. There are two fuelling and fluid stations on either track, entitled "A" and "B". A total of four vehicles can be refuelled simultaneously. There is only one semi-automated cleaning station on either track, located at the "B" service location. Vehicles fuelled at the "A" location must advance to the "B" location for interior cleaning. During interior cleaning, a cyclone blower attached to the front door is used to induce a vacuum. The fuelling attendant enters the bus through the rear door and uses an air wand to ensure that all debris is dislodged and pulled through the front door in the draught. All bus washing is done via an automated bus washer located at the end of track 2.

The windshield washer is topped up with a methanol-water mixture during vehicle servicing.

Servicing can take an average of 10 minutes per vehicle if each operation is to be performed sequentially; fluid check and refuelling, cleaning the vehicle interior, washing the exterior and other miscellaneous checks (including a check of lights, tire pressure and wipers) and shuttling the bus between the workstations. The vehicle must be restarted and driven between each station. Vehicle servicing rates vary depending on the time of day. As depicted in Figure II-3, the service section operates at capacity between 21:00 and 03:00 hrs when 12 buses per hour are serviced. The dips in service rate experienced at noon, late afternoon and early evening are due to meal breaks and shift changes. Generally, all buses are washed when practical.

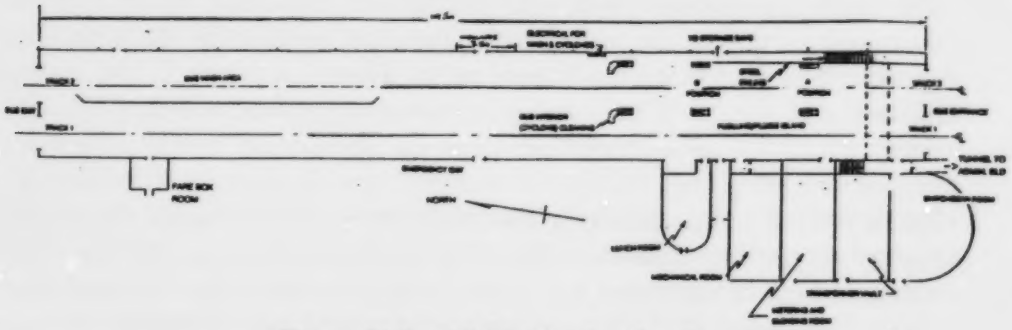

Figure II-2. Vehicle Service Bay Layout

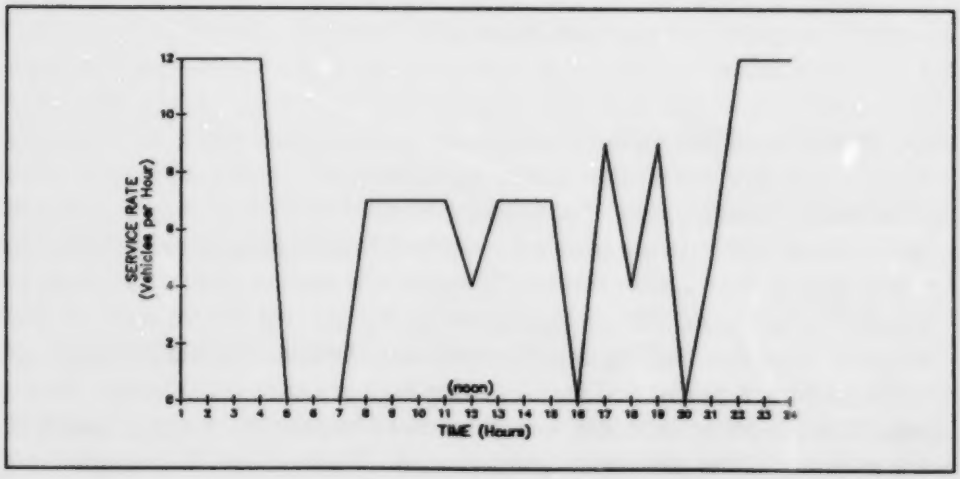

Figure II-3. Vehicle Servicing Load

The service bay is equipped with two drain grates running the length of each track. Plumbing from the drain grates runs to an oil-water separator pit located to the west of the service bay. Water, along with spilled fluids (primarily fuel) channeled through the drain grates, is run through the separator where fuel and oil accumulate for periodic removal. The remaining effluent, brackish water, is released into the sanitary sewer system.

There is also a mechanical ventilation system consisting of four 9.5 m^3/s (20,000 CFM) exhaust air fans. Exhaust vents are located at both the roof and floor level. Two fans are continuously left operating during the winter months, providing the equivalent of approximately 8 air changes per hour. During the summer months the system is not operated. Ventilation is provided through the entry/exit doors which are left open.

The main transformer room and mechanical room are located off the southwest portion of the service bay. Electrical switches for the ventilation system are located in the mechanical room. Electrical panels for the cyclone blowers and automatic bus washer motors are mounted within the service bay.

There is also a tunnel linking the administration building to the vehicle storage garage that runs under the south entrance of the service lane. The tunnel is used by drivers to get to and from their buses at the end of their shift. The tunnel stairwell emerges in the service bay along the common firewall shared with storage bay number 1.

Diesel fuel is stored outside the service bay in three 45,000 litre underground tanks. The tanks are located to the west of the service bay.

C. VEHICLE STORAGE

The vehicle storage area contains four bays identified as bays 1 through 4 respectively. All bays are physically isolated from one another by 2 hour fire walls. Storage bay 1, also entitled "B" section, is used to store cars, trucks and Handi-Transit buses. "B" section serves as the general service area for these vehicles. Gasoline fuelling is performed outdoors, just beyond the north exit, while washing is performed indoors using high pressure water hoses. Storage bays 2 and 3 house operable vehicles while bay number 4 stores buses that are awaiting either service or maintenance. Storage bays 2 through 4 each contain 12 tracks or rows of buses.

Each morning, the drivers start their assigned buses and allow the vehicles to idle while they perform their walk around inspection. Idle time can range from 2 minutes to 10 minutes. The discrepancy in time arises because the drivers must allow the vehicle to build up sufficient air pressure. In winter months, drivers allow their vehicles to warm up. These activities must all take place prior to the buses leaving the garage. Approximately 246 buses are dispatched between 05:00 and 07:00 hours in the morning. Rush hour buses return throughout the morning. The process is repeated in the afternoon when 146 buses are dispatched between 15:00 and 16:00 hours to handle the evening rush hour.

All drain pipe plumbing from "B" section and storage bay 2 is connected to the same oil-water separator as the service bay. A second oil-water separator pit, located to the east of the bus storage garage, captures effluent from storage bays 3 and 4.

The maximum air change rates in bay numbers 2, 3 and 4 are approximately 3.9, 4.0 and 3.8 changes per hour respectively. The system is augmented through a lateral transfer of air from the service area ventilation system. The ventilation system is only operated at capacity during the morning and afternoon dispatch. Even at the maximum air change rates, the drivers have made numerous complaints about air quality. Work is currently underway to upgrade the ventilation system. The upgrade work will include a computerized damper control system, using CO_2 monitors located throughout the storage area, to deliver additional makeup air to the areas of greatest need. Ventilation is facilitated by a mechanical system removing air at the floor and roof levels. Exhaust air pickup vents are evenly spaced along the length of the storage bays. The ventilation system is only capable of supplying part of the make-up fresh air load. The remaining make up air must infiltrate at door ways and around cracks or openings. The service garage is in a hypobaric (below atmospheric pressure) state during peak exhaust fan operation. The ventilation system will be more closely balanced in the future when the above mentioned above ventilation system modifications are completed.

D. MAINTENANCE SHOP

The maintenance shop, store room and head office share the same building. The maintenance and repair section is also referred to as "G" section. The Osborne Street maintenance facility is the primary repair shop for Winnipeg Transit and is capable of performing body work, painting, inspections,

electrical, engine and general repairs. The shop also includes a general machine shop and an electrical rebuild shop. The shop layout, illustrated in Figure II-4, consists of a large open work area. There are no physical barriers between the different vehicle repair shops. The lines shown in Figure II-4 are meant to designate the various repair areas. Only the steam cleaning area, store room and spray paint booths are physically isolated from the other repair shop areas. The area designated as the floor repair shop serves as the general repair shop.

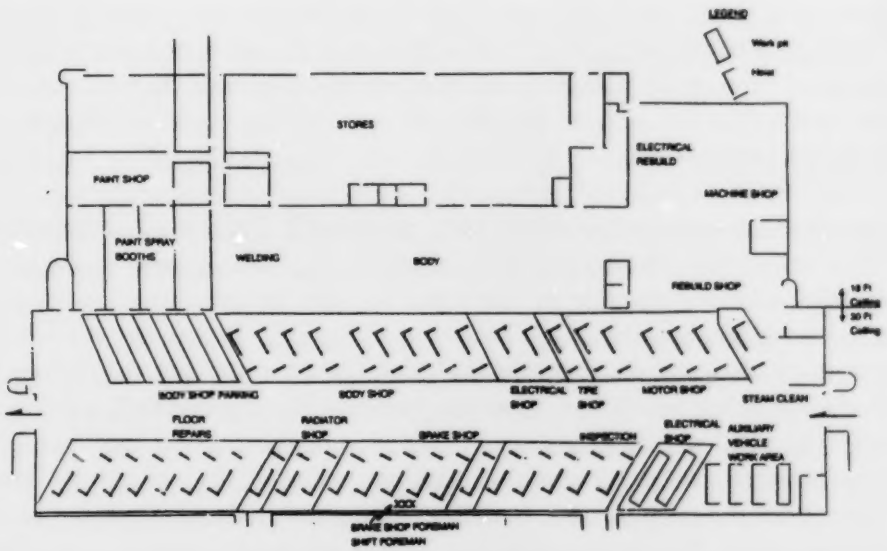

Figure II-4: Osborne Street Transit Base: Shop Layout

Two oil-water separators are used to prevent fuel, oil and other debris from entering the sewage system. Liquid spills collected from the south half of "G" section flow to a separator pit located to the southeast corner of "G" section. Drainage collected from the northern outside of "G" section flows into a separator pit located outside the facility.

Shop ventilation is achieved through a positive pressure system. Intake and exhaust vents are located throughout the shop.

E. MISCELLANEOUS

Winnipeg Transit has implemented a no-smoking policy which prohibits smoking in the paint spray area, battery storage room and oil storage room of the maintenance shop, as well as the general office area. Otherwise, smoking is permitted within the service, storage and maintenance areas.

There is direct supervision of all work areas during the daytime hours of 08:00 to 15:30 hours. There are foremen in charge of the service and maintenance areas. There is a marked reduction in supervision after those hours. The maintenance foreman then becomes responsible for the service area until 21:30 hours. At 21:30 hours, as activity reaches a peak in the service area, a night service foreman comes onto shift until 05:00 hours. However, his responsibility is extended to encompass the two other Winnipeg garages and he must travel between all three facilities.

Referring back to Figure II-1, there is also one 23,000 litre underground gasoline storage tank located north of storage bay 1 and a 114,000 litre above ground propane tank located to the northwest on the property. Gasoline powered automobiles and trucks are fuelled outdoors. Transit uses propane as a backup fuel in the natural gas fired heaters.

III POTENTIAL HAZARDS

A. INTRODUCTION

The use of any fuel poses a number of risks or hazards with respect to health, safety (fire and explosion) and the environment. The matrix in Table III-1 presents a simplified overview of the hazards. Liquid fuel, fuel vapours and exhaust emissions can be potentially fatal to humans. Examples of this are either direct contact or ingestion of fuel, or inhalation of either fuel vapours or exhaust emissions. Fuel vapours also pose a fire or explosion risk. To initiate and then support combustion, one requires fuel, oxygen and an ignition source. It is actually the fuel-air mixture that is burning. Liquid fuel was omitted from the fire and explosion category since liquid fuel will vapourize and feed the fire. Liquid fuel, fuel vapours and exhaust emissions also pose an environmental risk. For example, a fuel spill could lead to soil contamination. Exhaust emissions and fuel vapours may adversely affect the environment.

Table III-1: Hazard Summary

	HEALTH	FIRE & EXPLOSION	ENVIRONMENTAL
LIQUID FUEL	YES	NO	YES
FUEL-AIR VAPOUR MIXTURE	YES	YES	YES
EXHAUST EMISSIONS	YES	NO	YES

Differences in fuel properties have a direct impact on the relative hazard that one fuel poses compared to another. This chapter compares the properties of chemical grade neat methanol (100% methanol) to gasoline and diesel, and their impact on transit operations. Given that a certain event (e.g., fuel spill) is equally likely with either methanol, diesel or gasoline, it is the fuel properties that will affect the extent of the hazard. Table III-2 summarizes selected properties of methanol and typical diesel and gasoline blends.

Table III-2: Selected Fuel Properties

Property		Fuel Methanol	Diesel	Gasoline
Vapour pressure (RVP-kpa) (also volatility)		31.7	0.28 to 2.8	55 to 110
Flammability Limits				
Lower	Volume %	6.0	0.6	1.4
	Temperature (^{0}C)	7	21 to 96	-43
Upper	Volume %	36.5	7.5	7.6
	Temperature (^{0}C)	43	NA	-30 to -12
Autoignition Temperature (^{0}C)		385	225	220
Vapour Density (air = 1)		1.11	5 to 6	2 to 5
Diffusion Coefficient (m^2hr)		0.05	0.02	0.02
Flash Point (^{0}C)		11	52	-43
Heat of Combustion (KJ/kg)		19930	41870	43030
Heat of Vaporization (KJ/kg)		1177	267	349
Flame Spread Rate (m/s)		2 to 4	0.02 to 0.08	4 to 6
Electrical Conductivity (cu)		3*10^7	50 to 100	3 to 10
Time Weighted Average (TWA) - 8hr (ppm)		200	500	500
Immediately Dangerous to Life and Health (IDLH) (ppm)		25000	NA	5000
Water Solubility		Yes, and flammable up to 21% methanol to water (v/v)	No	No

Compiled from Ref (1, 2 , 3). NA denotes not available

1 Machiele, P. (U.S. EPA); A perspective on the Flammability, Toxicity and Environmental Safety Distinctions between Methanol and Conventional Fuels Paper Presented at the American Institute of Chemical Engineers, Phil., Pa. Aug. 1989.

2 Ref: Safe Handling & Testing of Alternate Fuels. Prepared by Mueller Associates Inc. for US DOE contract DE - ACOS - 79CS56051. January 1982.

3 Ref: Comparative Safety of Methanol - Fueled Buses in A Tunnel Environment. Report prepared for Triborough Bridge and Tunnel Authority by Arthur D. Little Inc. Report ref. #60219. Dec.,87.

Unlike diesel or gasoline, which are composed of a complex mixture of hydrocarbon species, methanol is a pure substance having discrete properties. It should be pointed out that the properties of gasoline and diesel will vary, depending on the blend of hydrocarbons. Properties of concern fall under the categories of flammability, and toxicity to man and the surrounding environment.

B. FLAMMABILITY

There are a number of issues of concern with flammability. Of initial interest is how readily a fuel can be ignited. Once ignited, concern will focus on how fast the fuel burns, are the flames visible and the amount of energy (thermal radiation) released to the surrounding zone.

Vapour pressure and flammability range

Vapour pressure is a measure of the volatility of a fuel or how fast it will evaporate. At higher vapour pressures, a greater mass of fuel will exist in vapour form compared to a fuel with a lower vapour pressure. The flammability range is a measure of the vapour concentration limits in air between which the mixture remains flammable. The temperature values correspond to the atmospheric pressure conditions at which the flammability limits are reached. There are two possible conditions to examine when evaluating fuel flammability and propensity to ignite; confined volumes such as a fuel tank and open areas such as the transit garage floor (e.g., fuel spill).

Gasoline is the most volatile of the three fuels under consideration, with a Reid Vapour Pressure (RVP) of 55 to 110 KPa, while diesel is at the other extreme with an RVP of 2.8 KPa. Methanol falls midway between the two fuels with an RVP of 31.7 KPa. Although gasoline is the most volatile of the three fuels, it has a narrow flammability range of 1.4 to 7.6% (V/V) vapour in air, corresponding to a temperature range of -43 to -21^{0}C. Thus a gasoline air mixture confined to a container, such as a fuel tank, is too rich to be ignited under most conditions. In open air situations, such as a fuel spill, gasoline will rapidly evaporate. The resulting mixture may then be within the flammability limits. Ignition could then be initiated by sources near the fuel spill. At the opposite extreme, the low volatility of diesel renders it relatively inert in open air situations. However, should the fuel be warmed inside the fuel tank, as in the case of recirculating fuel from a fuel injection system, the fuel temperature may climb above 53^{0}C, the lower flammability temperature limit.

Methanol poses a potential flammability hazard both inside a fuel tank and in open areas. Indoor vehicle storage will more than likely ensure that the fuel temperature stays within the flammable range of 7 to 43^{0}C year round. Within this temperature envelope, the fuel tank vapour would be flammable. Methanol can also pose a flammability hazard in open air situations. However, compared to gasoline, it has a much lower volatility and requires a greater vapour concentration to achieve the threshold flammability limit. In the event of a fuel spill within one of the transit garages, the spilled fuel will likely rapidly evaporate. With sufficient ventilation, the lower flammability limit should not be reached except near the spill itself. Compared to diesel, evaporation may prove to be an effective method to dispose of drips and very small spills. While the spill is present, it would constitute a potential hazard.

Fuel vapour dispersion

Vapour specific gravity and diffusion coefficient give a relative measure describing how fuel vapours will disperse. The vapour specific gravity is a measure of the fuel vapour density with respect to that of air. Methanol has a vapour density ratio of 1.11, which is close in weight to air, and will easily disperse compared to diesel and gasoline vapours, which are between 2 to 6 times heavier than air. Gasoline and diesel vapours will more easily settle to low lying areas such as work pits and drainage areas.

The diffusion coefficient measures how fast the vapour will diffuse throughout the atmosphere. Methanol has a diffusion coefficient of 0.05m^{2}hr which is over two times greater than that of either gasoline or diesel. Given the diffusion coefficient and vapour density of methanol, any methanol vapour released into open areas, such as the transit garage, will rapidly dissipate throughout the building avoiding any excessive build-up of a flammable vapour concentration. The ventilation system can be used to remove the fuel vapours.

Fire

Once a fuel has been ignited, properties such as the heat of combustion and vaporization, burn rate, boiling point and emissivity can give an indication of the relative heat release and burn rate.

Of the three fuels under consideration diesel fuel, with its extremely low volatility, is the most difficult to ignite. With a flame spread rate of 0.02 to 0.08 m/s, a diesel fire will start very slowly. Diesel fuel also has an extremely high heat of combustion to heat of vaporization ratio (156:1). Thus a diesel fuel fire will begin very slowly but begin to voraciously feed on itself and pick up.

The high volatility of gasoline and its rapid flame spread rate implies that gasoline can easily be ignited. Once ignited, a gasoline fire will spread rapidly. Similar to diesel, gasoline has a very high heat of combustion to heat of vaporization ratio (123:1). These conditions help to produce a rapidly spreading pool fire as illustrated by the flame spread rate of 4 to 6m/s. Methanol has less than one half the heat of combustion of either diesel or gasoline and a heat of vaporization over three times that of gasoline.

A fire also poses a threat to persons and properties outside of the immediate burning pool. The higher heat of combustion will mean more heat is radiated to the surroundings. Table III-3 presents temperature readings at various points above a burning pool surface for methanol and JP-5. JP-5 is a jet fuel with many characteristics of diesel fuel #1. The heat radiated by a methanol fire rapidly falls off, as evidenced by decreasing temperatures, whereas the temperature above the diesel fire remains constant over the distances under consideration. Part of the reason the methanol fire is hotter near the flame source can be explained by the absence of smoke which can absorb some of the heat flux. The overall higher heat flux from a diesel or gasoline fire can lead to greater property damage.

Table III-3: Temperature As A Function of Distance[4]

Distance Above Burning Pool Surface [cm]	Temperature [^{0}C] Methanol	JP-5 (Diesel)
1	750	500
40	500	500
120	250	500

4 Alger et al; Some Aspects of Structures of Turbulent Pool Fires. Fire Technology, Vol 22, #2. 1986.

Heat radiated by a burning pool can also be expected to cause casualties due to tissue burns. Within the burning pool, one can expect a 100% casualty rate. As the heat flux diminishes outside the burning pool, expected casualties and damage will diminish. Figure III-1 illustrates this phenomenon. Both diesel and gasoline with their higher heat of combustion can potentially cause more damage and a greater number of casualties than a methanol fire. Although Figure III-1 uses a heat flux value of 7.5kw/m^2, there is a general correlation amongst the work of different researchers relating incident heat flux to level of pain[5].

The United States Federal Safety Standards for Liquified Natural Gas Facilities (40 CFR, Part 193, 1980) suggest a threshold worst case flux of 5kw/m^2 for direct exposure of human beings. In a study prepared for the Triborough Bridge and Tunnel Authority, the authors reported that at a flux of 5kw/m^2, it would take approximately 13 seconds to achieve the threshold of unbearable pain on bare skin[6].

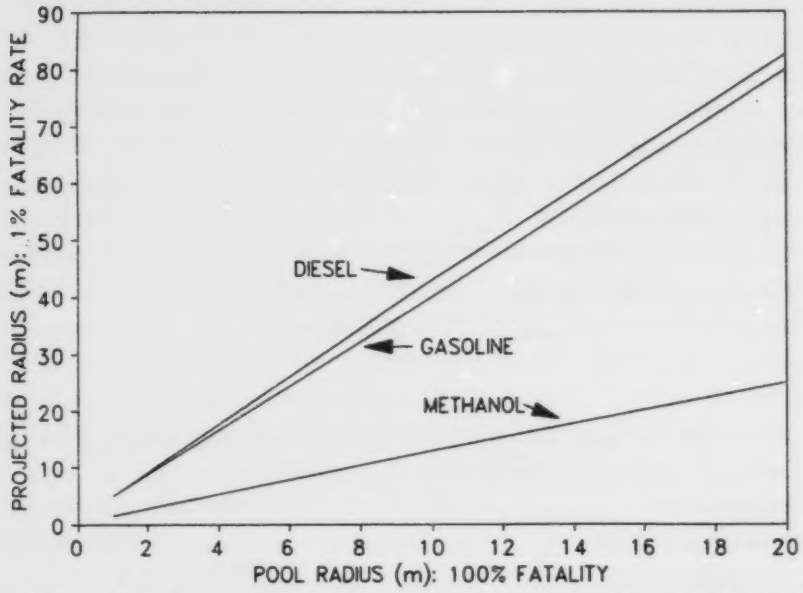

Figure III-1. Fatality And Damage Distance as a Function of Fire Radius[7]

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5 Comparative Safety of Methanol - Fueled Buses in A Tunnel Environment. - op cit.

6 Ibid.

7 Webb, R.F.; Assessment of Safety of Transportation, Distribution and Storage of Methanol Fuels. Report Prepared for Transport Canada, TP9519. September 1988. Figure extracted from report. Diesel fuel projection based on an extrapolation.

Neat methanol burns smoke free with a nearly invisible flame under daylight conditions. This poses a serious threat to people near a methanol fire. Without any other matter being combusted people may not be aware that there is a methanol fire. In addition to signalling the presence of a fire, smoke can absorb some of the incident radiation and trip a smoke detector (alarm system). Otherwise, an automatic fire detection system will have to rely on thermal or infrared detection techniques.

Conclusions Regarding Flammability

There is no absolute measure or ranking to positively rate the overall flammability of one fuel compared to the other. The fuel vapour within a methanol bus fuel tank will likely be in the flammable range throughout most of the year. During refuelling, methanol fuel vapours vented from the fuel tank would pose a flammability hazard. Therefore care must exercised to keep any ignition sources away from the filler neck and breather vent. Vapours that escape during the refuelling process should rapidly disperse compared to either diesel or gasoline. Since methanol vapours are lighter than those of gasoline or diesel and will easily disperse, it may be advisable to have explosion proof electrical fittings throughout the servicing, storage and maintenance areas.

In the event of a methanol fuelled fire there is likely to be less damage outside the fire pool compared with either gasoline or diesel. However, since methanol buses will carry at least two times the volume of fuel compared to diesel buses, the fire radius could be about 41% larger.

C. HEALTH

The primary health concern with a fuel relates to its toxicity to man. Fuel toxicity is a function of dosage, route of entry and duration of exposure. There are three principle routes for exposure:

1) respiration;
2) dermal/external; and
3) oral/ingestion.

Furthermore, the exposure can be acute (i.e., exposure to a significant quantity within a short period) or chronic (i.e. long term exposure). Respiration or inhalation of fuel vapours is the most likely route for exposure. The confines of a garage and the refuelling operation are but two examples of zones where persons may come into contact with fuel vapours. Dermal (or skin) contact is probably the second most common route for exposure. Dermal exposure is likely to occur during the refuelling operation, maintenance to the fuel system or during fuel spills. Ingestion of methanol through the gastrointestinal tract is potentially the least common route of exposure but can be the most serious. However, one should not discount the severity of a dosage absorbed through inhalation or through dermal contact. All routes of exposure can be potentially fatal.

Respiration

It is impossible to qualify which fuel is the most lethal; methanol, gasoline or diesel. Diesel and gasoline consist of blends of hydrocarbons which contain certain species that have been identified as, or are suspected as, carcinogens. These include aromatics such as benzene, toluene and xylene. Also diesel and especially gasoline, have a distinct odour and colour. Added to this is the fact of familiarity; people recognize either substance as a fuel. Therefore, people are more likely to recognize that they are being exposed to a fuel. Methanol is colourless. The threshold level value (TLV), the concentration at which people begin to detect its presence, for methanol vapour, is 53.5 ppm[8]. Furthermore, methanol has a connotation of being an alcohol, which can lead to ingestion. Methanol has an 8 hour time weighted average (TWA) exposure limit of 200ppm (based on habitual exposure) versus a 300-500ppm limit for gasoline and diesel. The 8 hour TWA is the maximum average dosage that a person can receive over an 8 hour period without suffering any adverse effects. Table III-4 presents different TWA limits for methanol as a function of time. Given the volatility of methanol compared to diesel and current refuelling practices, one is more likely to inhale methanol fuel vapours than diesel fuel vapours. This is not to minimize the severity of diesel vapour inhalation. The inhalation of diesel fuel vapours, particularly over the long term, is extremely dangerous[9,10]. However, diesel is considered too involatile to pose a serious short term risk.

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8 Genium Publishing Corporation; Material Safety Data Sheet - Methyl Alcohol. MSDS # 54, Revision C. Schenectady, NY. September, 1985. Odour recognition Threshold based on 100% of test panel.

9 Safe Handling and Testing of Alternate Fuels; - op cit.

Table III-4: Estimated Tolerance Values for Methanol Vapour[11]

Exposure (TWA)	Methanol Concentration in Air [ppm]
1 hour	1,000
8 hour	500
24 hour	200
5*8 hour working days	200

Skin contact

Dermal contact will most probably occur during refuelling and fuel system maintenance. Diesel fuel tends to be handled carelessly due to the perception that it is relatively inert. Although the fuel can be frequently spilled, its effects tend to be less severe in the short term than either methanol or gasoline. Gasoline can pose more of a danger than methanol. Relative to methanol, gasoline is rated more toxic in terms of skin penetration[12]. Either fuel will dissolve the natural oils secreted by the skin. Prolonged contact can lead to the fuel penetrating the skin and uptake into the body. The absorption rate of methanol into the skin is approximately $0.2mg/cm^2/min$. The solvent of these two fuels creates a tendency for people to use them as degreasing agents.

Ingestion

Unlike gasoline or diesel, methanol naturally occurs in the human body as a result of normal metabolic processes. Humans normally have a background level of approximately 0.5mg methanol/kg body weight. Methanol is introduced into the body through fruits, vegetables, alcoholic beverages and dietetic foods containing aspartame[13]. A fatal dose of methanol is estimated at approximately 300mg/kg of body weight (equivalent to ingesting 26 to

10 Methanol's Properties and Their Consequences; Reports prepared by Manitoba Research Council for SYPHER:MUELLER International Inc. under contract 84-IMRC-SC01. December 1986.

11 Webb, R.F.; - op cit.

12 Handbook of Analytical Toxicology, Chemical Rubber Co. 1975.

13 Machiele, P.A. - op cit.

70ml). The actual dosage is a function of body weight and background level in the body. Medical treatment exists to counter the toxicity of methanol poisoning but its effectiveness is dependent on the dosage ingested and the timing of medical treatment. There is no set antidote for diesel and gasoline ingestion. Overall, approximately 1.5% of all methanol ingestion cases resulted in a major medical outcome and 0.3% in death as compared to 0.19% of the gasoline exposures during the same period[14]. Thus if ingested, methanol is more likely to result in a more immediate and severe health effect or death. Therefore it is absolutely essential to educate transit personnel about the dangers of methanol ingestion.

Most instances of gasoline ingestion appear to be due to siphoning instances and accidental exposure by children. These two categories comprise approximately 39% and 36% respectively, of the 35,000 annual instances of gasoline ingestion[15].

Health Conclusions

Methanol, gasoline and diesel pose a health risk and are potentially fatal. Neat methanol, while cool to the touch, is clear and essentially odourless. Therefore it will take some re-education to ensure that transit employees become familiar with the fuel. Once educated, instances of intentional exposure with methanol are expected to be quite infrequent within a transit facility, given the professional nature of the operation.

The most probable routes of exposure to a fuel will be through inhalation of fuel vapours and contact with raw fuel during vehicle service and fuel system maintenance. Measures to protect staff against exposure to methanol are not expected to be much different than existing measures. Adequate ventilation is necessary to minimize the ambient fuel vapour concentration. Methanol has a TWA_{8hr} of 200 ppm, versus 300 to 500 for gasoline and diesel. Protective clothing and goggles are important for personnel exposed to fuel (methanol, gasoline or diesel), such as those on the fuel line and those in the maintenance shop.

14 Webb, R.F. - op cit.

15 Machiele, P.A. - op cit.

D. ENVIRONMENTAL HAZARDS

Since methanol is hygroscopic, water can be used to dilute a fuel spill or fight a fire. However, a methanol-water solution is flammable down to a mixture of 21% (v/v) methanol in water. Therefore, an abundant supply of water is required, or dilution with water will only increase the volume of flammable liquid. On the other hand, diesel and gasoline are insoluble in water and will rapidly stratify into layers. The oil film on top of the water can be picked up for disposal while the remaining brackish water is released into the sewage system. Depending on the methanol water concentration, disposal could pose a flammability and toxicity problem. Depending on the size of the fuel spill and the quantity of dilution water used, the spill could not be flushed into the sewage system. The mixture could constitute a safety hazard (flammability) and the alcohol could overwhelm the biodigestion process used during sewage treatment. A methanol concentration in excess of 5000mg/Litre (5ppm) can reduce the purification efficiency in sewage treatment plants[16]. A methanol release into the potable water supply could have especially deleterious consequences, given that a methanol water mixture is tasteless and odourless at low methanol concentrations, and could prove to be a fatal mixture. Assuming a fatal dosage level of 300mg/kg, this is equivalent to a 13000ppm methanol concentration based on a 2 litre daily fluid intake[17]. However, once methanol is mixed with water, normal biodegradation and dispersion should rapidly reduce the overall concentration. The recommended drinking water limit for methanol is 0.001mg/L (1 ppb).

Methanol is also corrosive and will attack certain materials including aluminum, zinc, copper and lead, as well as swell and crack certain elastomers and plastics. Appendix III-1 presents a partial listing of both compatible and non-compatible polymers. Any fuel wetted surfaces will have to be redesigned to ensure material compatibility.

Environmental conclusions

Methanol should not produce any long term toxic effects on the environment. Compared with either gasoline or diesel fuel, any spilled methanol would eventually be biodigested by micro-organisms within the soil and ground water.

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16 Breszkiewicz, E. et al; Effect of Methyl Alcohol and Ethylene Glycol on the Work of Activated Sludge, Acta Microbiol. Pol., Vol. 28, No. 3, pp255-260. 1979.

17 Machiele, P.A. - op cit.

Water can also be used to eliminate the flammability and reduce the toxicity hazard posed by methanol.

E. EXHAUST EMISSIONS

Methanol vehicles produce many of the same exhaust emission constituents as diesel and gasoline vehicles, although the quantities of individual gases and particulate matter vary depending on the fuel type, engine model and overall engine condition. Concern over exhaust gas emissions is likely to occur in all indoor areas where vehicles are left idling.

Methanol and gasoline powered vehicles produce significantly less particulate matter than their diesel counterparts. Particulate matter primarily consists of solid carbonaceous and sulfate residue due to incomplete combustion of heavier hydrocarbons found in the fuel and lubricant. Particulate matter is less than 10um in diameter, with the bulk being 1um or less. At this size, diesel particulate is considered inhalable and can settle in the lungs leading to respiratory disease. Particulate matter formed from heavy hydrocarbons can include polycyclic aromatic hydrocarbons (PAH), a suspected carcinogen. It has been estimated that risks due to diesel particulates could be reduced by 15% to 40% with alternative fuels[18].

Particulate emissions from methanol engines are primarily due to incomplete combustion of the lubricant. Techniques aimed at reducing oil consumption in diesel engines should also benefit methanol engines.

Table III-5 depicts engine emissions profiles for 1990 model year Detroit Diesel Corporation (DDC) 6V 92TA diesel and methanol engines along with pending U.S. 1991 emissions standards. DDC supplies engines to approximately 90% of the Canadian transit bus market. The emissions results indicate that the methanol engine satisfies pending U.S. emissions standards for all regulated emissions whereas, the present diesel configuration fails to meet the particulate standard. The addition of a catalyst to the methanol engine yields over a 50% reduction of particulate and aldehyde emissions and an 86% reduction in overall hydrocarbon emissions.

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18 Comments by C. Freed - Director, Manufacturers Operations Division, EPA (Washington). American Public Transit Association Conference, Los Angeles. April 1990.

Exhaust speciation has shown that both methanol and diesel engines emit a range of aldehydes primarily consisting of formaldehyde[19]. Compared with diesel engines, methanol engines emit significant amounts of formaldehyde. Concern over aldehyde and in particular, formaldehyde emissions, arises

Table III-5. Emissions Results[20]

Engine Type	HC(1)	CO	NO_x	PM	Aldehyde
Diesel; 6V92TA(2)	0.76	2.14	6.53	0.33	NR
Methanol; 6V92TA(3)	0.94	2.70	3.08	0.11	0.11
With Catalyst	0.13	0.27	3.08	0.04	0.05
1991 U.S.A. Emissions Standard (4)	1.70	20.80	6.70	0.34	--

(Units: GM/KW hr)

Notes: (1) Reported as organic mass hydrocarbon equivalent for the methanol engine.
(2) 1990 Engine build using #1 diesel fuel. "Production" methanol build.
(3) "Production" methanol build.
(4) Applicable to urban transit buses.

N.R. denotes not reported.

since formaldehyde is one of the most reactive organic substances. It has been classified as a group B1 probable human carcinogen. Within the atmosphere it can react with nitrogen oxides and ultra-violet (UV) radiation to produce photo-chemical smog (ozone). However, it should be noted that formaldehyde is naturally present in the atmosphere due to photo oxidation

19 Lipari, F. et al (General Motors); Aldehyde and Unburned Fuel Emissions from Methanol-Fueled Heavy-Duty Diesel Engines. SAE paper 860307.

20 S. Miller (DDC); DDC Methanol Engine Development Status. Proceedings of the 1990 Windsor Workshop on Alternative Fuels. June 11-14, 1990.

of hydrocarbons. Ambient formaldehyde levels will vary depending on the region or location. Table III-6 reports on various formaldehyde levels that have been recorded. Formaldehyde is also such a pungent gas that it can produce significant eye, nose and throat irritation in people at levels between 0.1 and 3 ppm[21]. The pungent odour and irritation might alert people to the presence of an exhaust gas build up in a poorly ventilated atmosphere.

In view of the concerns expressed about aldehydes, California has adopted an aldehyde standard for methanol vehicles. In the case of heavy duty methanol engines, aldehyde levels will be limited to 0.13 gm/KWhr beginning in 1993. Starting in 1996, aldehyde levels will be limited to 0.07 gm/KWhr. Both standards apply to new engines in the indicated model year.

Table III-6. Typical Ambient Formaldehyde Levels[22]

Area Concentration	Formaldehyde
Over Oceans	Up to 5ppb
In rural areas	Up to 12 ppb
Urban areas - Germany	
w/normal traffic	Up to 16ppb
w/heavy traffic	Up to 56ppb
In Los Angeles (determined in 1971)	Up to 165ppb

Vehicle exhaust emissions are likely to pose a problem during morning or afternoon start up. At this time, the majority of vehicles will be left idling. Engine emissions, particularly hydrocarbons, tend to be greatest immediately following start up. The engines will be cold and suffer from inefficient combustion, releasing unburned and partially burned fuel. Until the engine warms up or the catalyst achieves its light off temperature, HC and CO emissions will be high. This phenomenon is illustrated in Table III-7. Data

21 Kinney, Pil et al (Health Effects Institute USA); The Health Effects Institute Research Program in Methanol Toxicity. VIII Symposium on Alcohol Fuels. Tokyo, Japan. November 1988.

22 Kraft, J. et al - (Volkswagen work AG). See Footnote #8. P. 18)

was collected from two coaches, a methanol and diesel equipped with DDC 6V92TA engines[23]. Although both engines represent mid 1980's technology, they give an indication of cold engine emissions load. While a methanol engine will reduce the NOx and PM, CO and HC emissions increase with respect to the diesel. The methanol engine also ejects a large volume of unburned fuel, especially during cold engine idle. Data presented in Table III-7 can be used as a baseline to aid in the design of an adequate ventilation system.

Table III-7. Vehicle Exhaust Emissions[24]

Emissions Constituent	Cold Idle Emissions[(a)]		Hot Idle (gm/hr)	
	Methanol 1	Diesel Coach	Methanol 1	Diesel Coach
OMHCE[(c)]	1037	22	522	26
CO	452	50	282	22
NOx	35	138	52	137
PM	4	11	2.4	5.4
Formaldehyde	44	3	31	1.5
Methanol	2349	0	1173	0

Notes:
(a) Cold idle refers to emissions after vehicle start up. 11 minute sample time.
(b) Hot idle refers to emissions after the vehicle has been warmed up. 11 minute sample time.
(c) OMHCE: Organic Mass Hydrocarbon Equivalent.

23 Eberhard, G.A. et al (Chevron Research Company); Emissions And Fuel Economy Test Results For Methanol And Diesel - Fueled Buses. Presented at the Air & Waste Management Association, 82nd Annual Meeting & Exhibition, California. June 1989.

24 Eberhard, G.A. et al - op cit.

IV RISK ASSESSMENT

A. INTRODUCTION

The transit industry has been almost exclusively using diesel fuel for over 30 years. During that time, personnel have become well acquainted with the fuel. Although safety is a concern, diesel fuel is treated as a relatively inert substance. This attitude has grown out of years of experience gained from working with the fuel and the fact that relatively few serious incidents involving diesel fuel have occurred. There have been reports of fires on both diesel and methanol buses, but these have been few in number and not specifically related to functions performed on transit property.

The following section is a review of current operating practices at Winnipeg Transit and their possible outcomes. A review of operating practices is useful since it can highlight different types of precursor events (also referred to as hazard precursors) that can occur during transit vehicle operations. Hazard precursors can lead to one or more of three possible outcomes: fire or explosion, health, and/or environmental concerns. In the case of a transit fleet, the primary environmental concern would be due to a fuel spill. A fuel spill can occur as a result of a variety of reasons. The ambient fuel vapour concentration must be kept below the lower flammability point otherwise an ignition source may set off the fuel. It may not be sufficient to simply maintain the fuel vapour concentration just below the flammability limit. Personnel working in the area may be exposed to hazardous concentrations of fuel vapours. These outcomes can be tracked to numerous different preceding events. These can be unique events; i.e., a fuel spill occurs because "x" occurred, such as overfilling the vehicle. Or they can be a complex sequence of events because it takes more than one discrete action to result in a given outcome, i.e., a fuel spill occurs because "x" and "y" (etc..) occurred. This can include driving the vehicle away with the nozzle still attached. Based on these premises, one could construct complex fault tree diagrams detailing various sequences of events that can occur and their interrelationship to an ultimate event. However, the ultimate outcome could still be categorized as a fire or explosion, health and/or environmental concern. This report focuses on the ultimate outcome since there is not sufficient data available to identify or relate the probability of occurrence of different precursor events.

Data concerning precursor events is based on anecdotal recollections of Winnipeg Transit and other transit properties. Of the transit fleets surveyed, none kept detailed enough records to discriminate between events that transpire either on or off of transit property. Knowledge as to the types of events that can occur will form part of the risk management plan. It should be pointed out that this data is based on experience with diesel fuel. Given identical equipment operating with methanol fuel, people may adjust their work habits. Similarly, the mean time between failures (MTBF) for various pieces of equipment may be radically different if the fuel type were to change. However, the overall cause-effect relationship should hold.

Once different precursor events were identified, a simplified fault tree was used to examine the 3 hazards (fire/explosion, health and environmental) with respect to the three functional areas (service, storage and maintenance). Within a given functional area, as depicted in Figure IV-1, a certain event or sequence of events (hazard precursors) can lead to a fuel release. The term "fuel release" refers to any event(s) that causes fuel to come into contact with transit personnel, the environment or an ignition source. A release of fuel can lead to health and/or environmental hazards. There must be an ignition source in order for there to be a fire or explosion. All potential outcomes are assumed to be mutually exclusive. Activities or events that could result in a fuel release and an ignition source were also identified within each functional area.

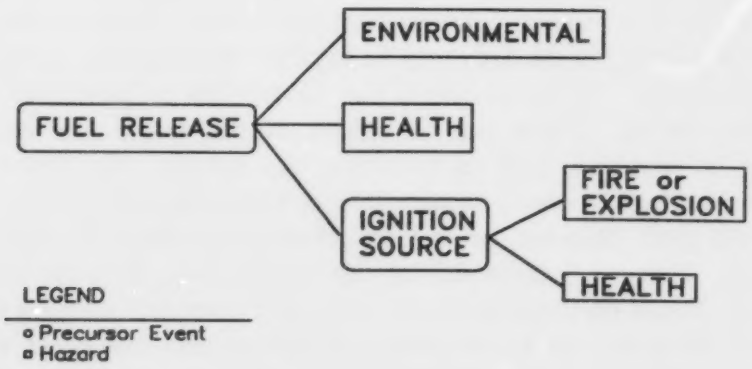

Figure IV-1: Simplified Fault Tree Approach

B. SERVICE OPERATION

There are basically three types of hazard precursors within the service area; fuel spills, fuel vapour and exhaust emission releases. The existing ventilation system is designed to remove air contaminants. A fuel spill is potentially the most dangerous hazard precursor since the fuel represents a possible health, environmental and fire hazard until it is disposed of. In addition to posing a potential hazard, spilled fuel represents increased operating costs. Fuel spills are chiefly caused by overfilling, pushing fuel out the tank breather or withdrawing the fuel nozzle before the fuel flow has been cut-off. Fuel spillage at Winnipeg has customarily been estimated by measuring the volume of fuel recovered from their oil-water separator. All fuel collected from the separator must be disposed of by an independent waste management firm hired to haul away waste fuel. Winnipeg has recently instituted a number of hardware and procedural changes on the service lanes aimed at reducing fuel spillage and hence controlling operating costs. This includes new fuel nozzles having a reduced flow rate of 91 L/min and instructing service personnel not to overfill the vehicles. Prior to instituting these changes fuel spillage was estimated at 36 litres/day. Preliminary reports estimate that these actions have resulted in a 65% reduction in fuel spillage.

In a study of self-service gasoline refuelling practices in the U.S., the authors reported that drips, involving a release up to 0.1 gm of gasoline, were the most common type of fuel release to occur with a conventional nozzle[25]. Even with a conventional refuelling nozzle set-up the operator must exercise judgement. Experience from the MILE program has shown that there can still be fuel drips with a "dry-break" connection nozzle. No refuelling system will entirely eliminate drips or spills. Small drips leaving coin sized marks should not present a problem since methanol will rapidly evaporate.

Spills can also result during a "drive-away". A drive-away occurs when the vehicle is accidently moved before an attendant has removed the fuel hose from the vehicle. This results in a hose breakage and fuel spillage. The pump will continue to pump fuel onto the fuelling apron until it is shutdown. To minimize fuel spillage, Winnipeg has installed a "break-away" valve which shears off the hose and blocks the fuel flow, limiting spillage to the contents of the sheared off hose, up to approximately 10 litres. One transit property

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25 EA Mueller Report; A Survey and Analysis of Liquid Gasoline Released To The Environment During Vehicle Refuelling At Service Station.

contacted reported that they have one "drive-away" every two months, the highest occurrence of any fleet contacted. Other transit fleets reported between 2 per year to 1 every 2 years. One "drive-away" every two months could be considered infrequent in a fleet of major size, given the quantity of vehicles serviced per day coupled with the time constraints placed on service personnel. The exact cause of one property's apparently high rate of "drive-aways" is uncertain; nevertheless, each occasion results in a fuel spill.

During service, vehicles will frequently be started and shut down as they are shuttled between the different work stations. Various vehicles may also be left idling in queues as they await movement to the next workstation. Without adequate ventilation, workers will be exposed to a wide range of air contaminants including aldehydes, carbon monoxide and unburned fuel. These emissions pose an immediate health hazard to employees.

During the refuelling process, fuel vapours contained in the fuel tank are displaced to the atmosphere. Fuel vapours can pose both a flammability and toxicity concern. Concern over the environment, in particular the photochemical reactivity of volatile hydrocarbons in gasoline, has led to the regulatory adoption of vapour recovery rules for gasoline refilling equipment in certain U.S. States. As of this writing Canada is only considering such controls and no regulations have yet been enacted. Recovery systems are designed to trap fuel vapours and prevent their escape into the atmosphere. There are no such requirements for diesel fuel nor are there any controls in place at Winnipeg. It has been estimated that during a 4 minute refueling cycle with methanol a person would be exposed to a 50 mg/m^3 concentration of methanol vapours. This is expected to add 0.04 mg/kg of methanol to the body burden[26]. Although the predicted dosage is quite minimal compared with the lethal dosage of 300 mg/kg, service personnel are likely to be exposed to low methanol vapour concentrations throughout their shift on a recurring basis.

The preceding discussion illustrates that fuel spills and releases can be a relatively common occurrence during the service procedure. The first column of Table IV-2A summarizes many of the likely causes of fuel spills under current operating practices (diesel fuel) along with their typical size. Spill sizes for various events were hypothesized based on information available from transit operators and an engineering estimate made by

26 Machiele, P.A. (EPA)- op cit. Extracted from Table 4. N.B. Assumes all inhaled methanol is absorbed across the respiratory epithelium. In all probability, less is absorbed.

SYPHER:MUELLER. The table also includes fuel vapour releases and exhaust emissions since these events also pose a potential risk. A relative probability rating was used to rank the frequency of occurrence of a given precursor event compared to other events. A relative probability rating was used since there is not sufficient data to generate quantitative probability functions for the different events. Thus an event that occurs more frequently than companion events would be rated as high. This does not necessarily imply that a specific event frequently occurs. Rather, it signifies that it is more likely to occur compared to other companion events.

Assuming a change to methanol fuel from diesel, without any changes to existing operating practices or hardware, then the relative probability rating of different hazard precursors should not change. The data in the first three columns of Table IV-2A (as well as Tables IV-3A and IV-4A) provide an overview of the most probable hazard precursors with either fuel.

The hazard assessment rating column of Table IV-2A refers to an overall assessment of the environmental, health and fire/explosion hazards with methanol fuel given that the hazard precursor has occurred. A "high" rating implies severe potential for damage (hence high risk) compared to other events in the same column. Each hazard is assumed to be independent. There can be an environmental hazard, such as a fuel spill into the sewer or seepage into the soil, without any other hazard such as ingestion or skin contact by transit personnel.

Referring to Table IV-2A, prematurely removing the fuel nozzle is rated as one of the most likely causes of a fuel release and typically results in a spill of minor size. Conversely, events such as a fuel hose failure or nozzle latch failure are less likely to occur and are rated as "low". Assuming either precursor has occurred, an overfilled vehicle poses a "low" environmental hazard compared to either category of fuel hose failure. Overfilling a vehicle will release very little fuel into the service area, whereas a fuel hose failure can result in a much larger volume of fuel being released under uncontrolled conditions. A similar analogy can be made with regards to the safety assessment. A fuel spray or mist dispersion due to a fuel hose rupture poses the greatest danger to employees in the immediate vicinity.

The occurrence of a fire or an explosion is a rare event, but nevertheless is an event that can occur during the service process. A fire or explosion in the service bay can occur as a result of a fuel spill being ignited, failure to turn off the motor during fueling, failing to ground the vehicle during refuelling, a spark igniting a fuel vapour cloud and so forth. These events should be

considered independent from fuel spills. A fire can occur only if there is an ignition source, fuel and oxygen. Table IV-2B identifies some potential ignition sources within the service area. Certain precursor events, such as dropping a lit cigarette or match into a pool of diesel fuel would have no effect. However with methanol, the pool would be ignited. The relative probability rating is a subjective ranking used to estimate which potential ignition sources are of the greatest concern. It is strictly a comparative evaluation of different potential ignition sources. For example, an improperly grounded vehicle is more likely to ignite any exposed fuel compared to an ignition source within the service bay. Hence it was assigned a "medium" rating.

The combination of Tables IV-2A & B, help identify which hazard precursors pose a significantly "greater risk" during methanol operation.

Referring to the list of hazard precursors identified in Table IV-2A, small scale fuel releases are rated as the most likely to occur. However, large scale methanol releases, due to a fuel dispenser or vehicle fuel system failure, pose the greatest environmental risk. There are no mechanisms to contain methanol or prevent it from escaping into the sewage system with the current design in place at Winnipeg. A spray or fuel mist due to a hose rupture, exhaust emissions, and fuel vapours released during fuelling pose the greatest health risks. A fuel spray or mist, along with other large scale fuel releases pose the greatest fire or explosion risk. From Table IV-2B, smoking is the most likely ignition source within the service area. An improperly grounded vehicle is the next most probable ignition source.

C. VEHICLE STORAGE

The primary concerns within the storage garage are an exhaust emissions build up and methanol fuel system leaks. Either of these precursor events poses a potential hazard.

Vehicle exhaust emissions are likely to pose the most serious problem during morning or afternoon start up. At this time, the majority of vehicles will be left idling. Exhaust emissions, particularly hydrocarbons, tend to be greatest immediately following start up. The engines will be cold and suffer from inefficient combustion, releasing unburned and partially burned fuel (in the form of aldehydes). Until the engine warms up or the catalyst achieves its light off temperature, HC and CO emissions will be high.

Table IV-2A. Hazard Assessment - Vehicle Service

Hazard Precursor	Typical Spill Size (Litres)	Relative Probability Rating	Hazard Assessment		
			Environment	Safety	Fire/ Explosion
Fill Hose Failure	50-200	Low	1 Medium 2 High	High Medium	High Medium
"Drive-Away"	<10	Medium	Medium	Low	Low
Overfill Vehicle	<5	Medium-High	Low	Low	Low
Remove Nozzle While Filling	<5	Very High	Low	Low	Low
Leaky Vehicle Fuel System	<5	Medium	Low	Very Low	Low-Medium
Traumatic Fuel Tank Failure	< 10	Very Low	Very High	Medium	Medium
Fuel Nozzle Latch Failure	10-50	Low	Medium	Medium	Medium
Vapour Released During Filling	NA	Very High	Low	Medium High	Medium
Vehicle Exhaust Emissions	NA	High	Low	Medium High	Very Low

Notes on Table:

1 Fuel hose rupture characterized by fuel spray or mist
2 Fuel hose failure characterized by a stream of fuel from the hose or a fitting
NA denotes not applicable

Table IV-2B. Ignition Sources Within Vehicle Service Area

Ignition Source	Relative Probability Rating
Smoking	High
Improperly Grounded Vehicle (Fuelling)	Medium
Ignition Source Within Service Bay	Low
Hot Exhaust System	Low

Some of the older Winnipeg transit buses leak fluids, including fuel. Fluid leaks are either absorbed by a desiccant or dirt on the floor, or work their way into the drainage system. Full scale sweeping operations are conducted almost daily and this will dispose of fuel spills on the work floor. The daily fuel and oil loss that works its way into the drainage system amounts to approximately 0.6 litres/day (based on 4000 litres recovered from the oil-water separator over the past 20 years). Although individual leaks may be relatively small in volume, they pose a particular hazard since smoking is currently permitted within the bus storage area. Slow fuel leaks or drips from methanol buses can be relatively difficult to detect. Fuel pressure may be sufficient to operate the vehicle without the driver noticing a fuel leak, particularly on a system that circulates excess fuel. Furthermore, the entire contents of a fuel tank could slowly drip out over the course of a day or two, such as the case if the bus were laid up during a weekend or holiday period. It is anticipated that small puddles due to methanol leaks will rapidly evaporate without leaving any telltale drip marks or dark puddles under the vehicle.

A major fuel system failure, although very unlikely, poses a severe hazard. Similar to the situation within the service or maintenance area, the storage area is designed to handle a large scale fuel release. Any effluent that enters the drainage system would pass through an oil-water separator. However, a methanol-water mixture would eventually enter the sewage system. A fuel

leak may not immediately be recognized because of the close proximity of buses to one another and minimal employee pedestrian traffic. Access to the fuel spill will be somewhat hindered because of the vehicle parking arrangement. Until the fuel is disposed of, it also represents a severe fire hazard, notably with regards to damage to adjacent vehicles.

The effect of the bus parking layout cannot be under emphasized in the event of a fire. One transit facility reported a severe fire within the storage area involving a diesel powered bus. The parked vehicle "spontaneously" erupted into flames. Fortunately, it was at the head of the line and was able to be pushed out of the storage area limiting damage to the burned bus itself. The fire was suspected to have been caused by a shorted electrical cable in the engine compartment that heated and eventually ignited some fuel and oil within the engine compartment. However it was merely a matter of coincidence that the bus erupted into flames while in the storage area. It is believed that the fire was already smoldering when the bus was returned to the storage garage.

Table IV-3A summarizes various hazard precursors within the storage garage along with their relative probability rating and overall hazard assessment. Small scale fuel releases (less than 1 litre) and exhaust emissions are the most frequently occurring hazard precursors. These events are not expected to pose a severe environmental hazard. Small fuel spills are expected to rapidly evaporate. Exhaust emissions present the greatest risk to employee health. A vehicle fuel system failure, although a relatively rare occurrence, has the potential to pose the greatest risk in terms of environmental damage and loss due to fire or explosion.

Table IV-3B summarizes different ignition sources. Smoking is rated as the most probable ignition source under a methanol fuel scenario. A hot exhaust system is likely to pose a risk if there is a fuel system leak within the engine compartment.

D. VEHICLE MAINTENANCE

The vehicle maintenance shop operates around the clock; vehicles are continuously being shuttled in and out for routine maintenance and repairs. During the course of this work, vehicle engines can be operated, exposing personnel to exhaust emissions. Exhaust hoses are used to vent vehicle exhaust outdoors.

Table IV-3A. Hazard Assessment - Vehicle Storage

Hazard Precursor	Relative Probability	Hazard Assessment		
		Environment	Health	Fire/ Explosion
Small Fuel System Leak (<1 Litre)	Very High	Low	Low	Medium
Major Fuel System Leak (up to 1100 Litres)	Low	High	Medium	High
Fuel Evaporation from Vehicle Fuel Tank	Medium	Low	Medium	Low
Engine Exhaust Emissions	Certain	Low	High	Low

Table IV-3B. Ignition Sources Within Vehicle Storage Area

Ignition Source	Relative Probability Rating
Smoking	High
Electrical Spark	Low-Medium
"Hot" exhaust system	Low
Building repair activities (e.g. welding)	Low-Medium

There is also an environmental risk due to fuel spills. Fuel is likely to be spilled during routine fuel system maintenance. During extensive fuel system repairs, the fuel system must be drained and the fuel stored in a portable tender until repairs are effected.

Unlike the service and storage area, the maintenance area includes shop functions, such as grinding and welding which are potential hazard precursors. A fire could also be ignited by a careless smoker. Fires can typically occur during welding, when a red hot spark or piece of slag ignites some grease or a mixture of fuel and oil in the base of a work pit. The fires would probably be minor in nature, rapidly extinguished and not result in any property damage. There have been no major or uncontrolled fires within the maintenance area at Winnipeg Transit. However, one transit facility reported a catastrophic explosion resulting in a fatality. The explosion occurred when an employee attempted to cut the straps off a fuel tank with an acetylene torch after the tank had been flushed with methanol. This illustrates that any fuel system work which involves grinding, welding or any other ignition source, must be approached cautiously. Methanol does offers an advantage over gasoline or diesel. The fuel system can be drained and then flushed with water to remove all traces of methanol. Prior to returning the fuel tank into service, methanol can be used to remove the remaining traces of water.

Table IV-4A summarizes and compares the relative severity of various hazard precursors within the maintenance area. A small scale fuel release, during routine maintenance for example, is the most frequently occurring hazard precursor. However this event is not rated as posing a significant hazard relative to other events. A large scale fuel release, such as the release of the entire contents of a vehicle fuel tank, poses the greatest risk with respect to the environment, health and fire or explosion.

Table IV-4B identifies and rates potential ignition sources. Smoking is rated as the most probable ignition source within the maintenance area, followed by sparks from shop operations. Both of these potential ignition sources are to some degree "controllable". Restrictions or changes in operating procedures can be implemented to reduce the risk posed.

Table IV-4A. Hazard Assessment - Maintenance Area

Hazard Precursor	Relative Probability	Hazard Assessment		
		Environment	Health	Fire/ Explosion
Small Fuel Spill e.g. Routine Maint. (<1 Litre)	Very High	Low-Medium	Medium	Low
Major Fuel Spill e.g. Entire Tank Contents (up to 1100 Litres)	Low	High	High	High
Exhaust Emissions	Certain	Low	Low-Medium	Low
Evaporating Fuel from Fuel Tank and Fuel Spills	Medium	Low	Low-Medium	Medium-High

Table IV-4B. Ignition Sources Within Maintenance Area

Ignition Source	Relative Probability Rating
Smoking	High
Sparks From Shop Functions (eg., welding, grinding, etc.)	Medium
Spark (eg. electrical equipment)	Low

V REGULATORY REVIEW

A. OVERVIEW

The three principal safety codes that regulate the handling of flammable and combustible fuels in Canada are the National Building Code (NBC), National Fire Code (NFC) and National Electrical Code (NEC). The combination of these codes comprises a set of technical requirements designed to protect human lives and minimize the social and economic damage on communities.

Provinces have generated their own legislated codes which generally encompass the national codes with slight modifications. Similarly, municipal codes generally comprise provincial codes but can be modified to satisfy peculiarities of a given area. In addition to the building, fire and electrical codes, certain jurisdictions also enforce other codes (e.g., environmental codes).

The prescribed treatment for storage and transfer of volatile liquids depends on the characteristics of the liquid, in particular the flash point. Volatile liquids can be identified as either a combustible or flammable liquid. Based on its flash point, methanol is rated as flammable, whilst diesel is rated as a combustible liquid.

B. PROVINCE OF MANITOBA

Manitoba regulations were reviewed and regulatory authorities contacted with respect to the question:

> "What are the applicable regulations if transit operations at the Osborne Street Transit Facility were to be switched over to methanol bus operation with the premise of indoor fuelling, storage and maintenance?"

The province of Manitoba has legislated its own set of codes which are basically the national codes with slight modifications. The applicable Provincial codes include:

- Manitoba Building Code (MBC)
- Manitoba Fire Code (MFC)
- Manitoba Electrical Code (MEC)
- Manitoba Workplace Safety and Health Act (MWSHA)

Transit operation with methanol fuel presents a new challenge to regulatory authorities and the transit operator. Existing regulations applicable to flammable liquids are generally tailored towards gasoline.

Within the City of Winnipeg, various municipal departments, including the Fire Department, Building Inspection Division of the Planning Department, City Waterworks and Waste Disposal and Employee Occupational Safety and Health Division are responsible for ensuring compliance with all Provincial Codes. Municipal departments only contact provincial authorities when their assistance is required.

The Osborne Street Transit Facility was originally certified to refuel, repair and store diesel buses indoors.

The bulk of the regulatory framework in Manitoba is concerned with structural and electrical components in the area where fuels are handled and ensuring adequate training for personnel. Many sections of the code that would pertain to a methanol scenario are equally applicable with diesel fuel. Discussions with municipal officials reveal that there should not be any major obstacles to gaining regulatory approval for the proposed facility provided that the installation satisfies all regulatory provisions applicable to flammable liquids. However, no final ruling could be given by authorities until an application is formally filed. The notion of methanol as a widespread transportation fuel has only been considered in recent years. Until regulatory authorities and their enforcement branches, as well as the general public become familiar with the fuel, there is bound to be a difference in opinion as to what constitutes safe handling.

The following is a summary of the major highlights of regulations pertaining to flammable liquids. A more complete citation of the applicable regulations can be found in Appendix 2.

- All open flames or flame producing devices, such as natural gas powered air heaters, are strictly prohibited within the service area. Smoking is also forbidden. The service, storage and maintenance area would also have to be kept clear of any combustible materials such as oily rags, paper, etc.

- The transit operator must develop a fire prevention and safety plan that includes: emergency procedures in case of fire, appointment of designated personnel to carry out fire safety duties, the control of fire hazards, and maintenance of the facilities to ensure adequate fire safety.

- The applicable sections of the electrical code limit electrical motors (e.g., fuel pump), control panels, lights, switches, wires and other electrical devices that may produce sparks or arcs within hazardous areas. Only equipment that is essential to the process and rated for service within a hazardous zone is permitted. Hazardous classifications for electrical equipment are a function of the type of gas, vapour or dust that is present in the atmosphere. Atmospheres containing flammable gases or vapours fall under Class 1, the most stringent rating, whereas electricals located in the presence of combustible vapours must meet Class 2 standards. Various sub-classifications, entitled divisions, have evolved to differentiate the severity of risk within a given classification.

  The Manitoba regulations make no specific reference to hazardous areas associated with indoor fuelling of flammable liquids. Two hazardous zones are defined around a fuel dispenser located outdoors. The first zone is defined as 1.2 m vertically above the grade and 0.45 m horizontally from the dispenser nozzle boot, while the second zone extends 6 m horizontally beyond the first zone at a height of 0.45 m above the grade. The first zone requires Class 1, Division 1 electricals[27] whereas the second zone requires Class 1, Division 2 electricals[28]. The hazardous zone within the storage and maintenance areas would consist of any area up to a level of 50 mm above the grade. Class 1, Division 2 electricals would be required within those areas.

- There must be appropriate control measures to prevent the release of any substance (i.e. fuel) which could create a hazard to public safety or health. Thus any material deemed to be a toxic or flammable substance cannot be released into the public sewage system.

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27 According to the Manitoba Electrical Code, Class 1, Division 1 hazardous locations include locations where volatile liquids are transferred. (Appendix B with reference to Chapter 18, MEC. Fourth edition).

28 Class 1, Division 2 includes locations where flammable gasses are present, but controlled. The actual classification of a Class 1, Division 2 area is some what arbitrary and subject to the discretion of licensing authorities. (Appendix B with reference to Chapter 18, MEC. Fourth edition).

- Ventilation is governed by both the MFC and MWSHA. The MFC limits the vapour concentration of methanol to 1/5 the lower flammability point (1.2% by volume, methanol in air) for fire safety reasons. The MWSHA limits the concentration of methanol as well as other air contaminants for health reasons. In the case of methanol vapour, the MWSHA of 200 ppm (8 hour TWA) would be the limiting factor. Appendix 3 contains a listing of TWA and STEL ratings for fuel and exhaust emissions constituents.

Although the codes are written from a general sense for flammable and combustible liquids, there appears to be certain provisions that are explicitly concerned with diesel and gasoline properties. The introduction of methanol may pose new questions. For example:

(1) Provincial and municipal environmental statutes currently do not permit the disposal of either flammable or toxic substances down the sewer system. Methanol presents somewhat of an ambiguity. Compared to either gasoline or diesel, it can be rendered inflammable via dilution with 5 parts water to 1 part methanol. Normal biodegradation and dispersion of methanol in an aquatic ecosystem will neutralize its toxicity. However neat methanol still can not be released into the sewage system, nor can it, under existing regulations, be diluted and released into the sewage system.

(2) The definition of the term "hazardous zone" may have to be re-examined. Although methanol has a greater flammability range compared with gasoline (6 to 37% versus 1 to 8%), its vapour has a lower specific gravity than that of gasoline (1.11 versus 2 to 5). Therefore methanol vapours will more readily disperse and not settle like gasoline vapours. In the event of a ventilation system failure or in poorly ventilated areas, a methanol vapour concentration could enter its flammable range. From a strict interpretation of the MEC, all electrical equipment in the service bay would have to meet Class 1, Division 1 standards or be relocated. There also could be some ambiguity with respect to the hazardous area within the storage and maintenance area. The regulations presently call for Class 1, Division 2 rated electrical equipment within the hazardous area. However, it may be necessary to increase the hazardous area beyond the 50 mm height in the storage and maintenance areas given the lower vapour density of methanol and its dispersion capability. Methanol vehicles

will require an effective vehicle fuel vapour recovery system to control fuel vapour escape during normal temperature cycling of the fuel tank (diurnal losses). Division 2 electrical equipment is, strictly speaking, limited to regions where flammable vapours are expected to be totally confined within vehicle fuel tanks.

C. PROVINCE OF ONTARIO

Ontario has adopted a series of regulations that govern the design of facilities where motor fuel is dispensed. Similar to the situation in Manitoba, the provincial regulations are drawn from federal codes.

The applicable Ontario regulations are identified in Table V-1 below. Many of the Ontario Provincial Statutes draw upon National Fire Protection Association (NFPA) criteria.

Table V-1: Summary of Ontario Regulations Applicable to Fuel Handling

Occupational Health and Safety Act Ontario
Ontario Hydro Electrical Safety Code
Ontario Fire Code
Gasoline Handling Code (Ontario)
Ontario Energy Act

There are no major differences between the intent of Ontario and Manitoba regulations. Differences primarily arise in the agencies charged with administering and enforcing the regulations. Ontario appears to be one step ahead of Manitoba in terms of an indoor fuelling standard. The Province of Ontario has produced a draft specification for indoor fuelling with gasoline[29]. The specification summarizes the relevant sections of Ontario regulations for indoor fuelling into one document. However, compliance with the document does not necessarily ensure that a given facility will be licensed for indoor fuelling. Its existence is probably related to Ontario's heavy dependence on the auto industry, which fuels automobiles as they roll off the assembly line.

29 Fixed Dispensing of Gasoline Inside Buildings; Ontario Ministry of Labour, Industrial Health and Safety Branch. Engineering Data Sheet 4-10 dated January, 1987.

Applications for an indoor fuelling facility in the Province of Ontario would be directed to the Ontario Ministry of Consumer and Commercial Relations and the Ministry of Labour. The Ministry of Consumer and Commercial Relations would review the plans and check for compliance with respect to the Gasoline Handling Act while the Ministry of Labour would consult the Gasoline Handling Act and the Health and Safety Act.

D. REGULATORY REVIEW CONCLUSIONS

In both Manitoba and Ontario, there are no specific regulations pertaining to the indoor dispensing of methanol as a motor vehicle fuel. Provincial regulations that cover indoor dispensing of motor vehicle fuel have evolved based on the use of gasoline and diesel fuel. Using criteria established for flammable liquids, authorities in both provinces do not feel that there are specific barriers preventing indoor methanol fuelling. However, there are no indoor methanol refuelling stations in Canada or elsewhere. Therefore it may be premature to discern whether regulatory authorities will ultimately issue the necessary operating permits for an indoor fuelling operation.

With increasing interest in methanol and other alternate fuels, it may be time to re-evaluate regulations pertaining to dispensing of motor vehicle fuels.

VI RISK MANAGEMENT PLAN

A. APPROACH

A risk management plan must address all regulatory constraints and satisfy concerns raised by the personnel who will ultimately operate the facility and their insurers. The preceding sections highlighted differences in fuel properties and identified events that have arisen or could theoretically arise, on Winnipeg Transit property. Although different hazard precursor events could occur during any of the three phases of vehicle operation (i.e., service, storage and maintenance), this analysis will emphasize the vehicle service function. There is a great deal of interest in this particular activity given that indoor fuelling is not normally performed with "flammable" fuels.

There are numerous possible approaches or actions that can be taken to guard against different hazard precursors. The ideal risk management plan offers the most cost effective solution that addresses all concerns raised by the transit facility and its insurers while satisfying all regulatory constraints.

The regulatory constraints summarized in Chapter V provide a baseline list of actions and procedures that must be satisfied. Adherence to the regulatory code should be sufficient to address many of the different hazard precursors that were identified in Chapter IV. In addition, various hardware modifications and/or changes in operating procedures can be implemented in order to prevent or reduce the frequency of those hazard precursors. A "ground-up" approach can be used to address specific concerns raised by the transit facility and its insurers.

Once a given hazard precursor has occurred, a series of specific actions or hardware can be employed to mitigate any subsequent environmental, safety or fire/explosion hazard. For example, Winnipeg Transit utilizes "break-away" valves to reduce diesel fuel loss in the event of a drive away.

First and foremost, effort should be placed on mechanisms or defences that avoid creating a hazard. Different defences, such as proper training, can provide a relatively low cost approach to risk management. Employee training, which must be performed (Manitoba Fire Code), provides an

effective means to inform transit staff, reduce incidents (hazard precursors) and permit a controlled response in the case of an event. Employee training was recently employed to reduce the frequency of fuel spills during vehicle servicing. The old axiom that an ounce of prevention is worth a pound of cure is equally applicable here too. Once a fuel spill, for example, has occurred, the costs of containing and cleaning it up can rapidly escalate.

The ensuing discussion identifies various risk management schemes that can be applied at the Osborne Street Transit Facility. For the sake of clarity, the different risk management proposals are segregated by function; vehicle service, storage and maintenance. Anticipated costs for the proposals are also included where data was available. Cost estimates are based on SYPHER:MUELLER International's experience with the MILE program and discussions with the transit industry. Without a definitive statement regarding the equipment or features that regulatory authorities will eventually insist upon, the following risk management plan serves as a general guide. Most of the proposals presented herein should apply at other transit facilities built for diesel applications.

B. VEHICLE SERVICE

The vehicle service area has been designed to conform to statutes covering the transfer of a combustible liquid. In the switch over to methanol, some of the equipment can be retained, however much of the service area will have to be extensively modified to conform with safety regulations. At this time it would also be prudent to add additional features to the facility and vehicles in order to further reduce the risk of fuel spills and control fuel vapour releases. Small scale fuel spills were previously identified as the most likely hazard precursor. The avoidance of fuel spills is given heavy emphasis; unlike diesel fuel, methanol is a flammable liquid which can not be disposed of in the existing oil-water separation system. Overall, the changes proposed in this report can be categorized as modifications to the fuelling area or the overall service structure, changes in operating procedure and vehicle modifications.

Changes to the fuelling area

The entire fuelling area, located at the south end of the service area, will have to be modified to accommodate methanol fuel operations. This includes all fuel dispensing equipment. The fuel dispensing rate will have to at least be doubled from its present rate of approximately 91 litres/min to

accommodate the present vehicle processing rate of approximately 4 minutes per fuelling (10 minute turn around time). Experience gained from the MILE (Methanol In Large Engines) Program has indicted that the flow rate can be increased to 190 litres/min (50 USGPM). The fuel pumps must be located outside of the fuelling area. They can be maintained in their present location (submerged inside the fuel tank) or alternatively positioned beyond the fuel tank but outside of the fuelling areas. Only the fuel nozzles, a minimum length of delivery hose and rigid pipe, flow meters and fuel pump controls should be located in the service bay. This design will remove the fuel pump from the service area and reduce the length of piping that is pressurized. An excess flow valve can be used to stop the fuel flow and limit spillage in the event of a traumatic failure on the pressurized side of the fuel hose. The Manitoba Fire Code (MFC) requires that there be at least two fuel pump cutoff switches (or valves). The primary switch can be located next to the fuel dispenser meter, similar to retail pumps, and would act as a reset switch for the fuel meter. The second switch must be located outside of the hazardous area. In addition, a temperature sensitive valve should be installed on all rigid fuel lines entering the service area. The valves would act as an emergency trip to cut off fuel flow into the service area at some prescribed temperature. All fuel pipes leading to the service bay should be buried well below the surface to avoid damage. Overhead fuel lines would be maintained within the service bay. Overhead fuel lines will enable service personnel to spot leaks. The break-away valves on the fuel hoses should be retained.

Given the increased volume of fuel dispensed to each vehicle, a flow meter with totalizer should be used to control the quantity of fuel dispensed into each individual vehicle. The totalizer would act as a feedback link and limit the volume of fuel dispensed to any single vehicle. This could be some function of vehicle fuel tank volume, for example 85% of total tank volume. The meter would then be reset for each vehicle. In the event of a traumatic fuel hose failure, the total fuel release would then be limited. This set-up could also limit overfilling in certain instances. The system could also be tied into a fleet management system which would provide detailed reports on fuel consumption by individual vehicles.

Fuel dispensing equipment will also have to be equipped with a ground strap in order to conform with the MFC. The ground strap can either be an external cable which is attached to the vehicle prior to affixing the nozzle or alternatively, an integral part of the fuel nozzle assembly. A meter can be used to visually or audibly signal that a ground connection has been made. A

"dry-break" fuelling nozzle is recommended to minimize fuel spills and control fuel vapour releases. A dry-break nozzle would permit a positively sealed connection between the nozzle and fuel filler assembly thus avoiding fuel spillage and vapour escape around the filler neck. A vapour recovery system can also be used to limit the discharge of fuel vapours from the vehicle fuel tank during refilling. The vapour recovery system would consist of a hose which positively connects to the fuel tank breather vent. All displaced fuel vapours would then be returned to the underground fuel storage tank. Both "dry-break" fuelling nozzles and vapour recovery systems are now commercially available for methanol fuelling stations.

The longitudinal spacing between fuelling station islands, as depicted in Figure II-2, is approximately 1 bus length (12m) apart. Although not specifically called for in Manitoba regulations, this spacing should be increased to at least 1.3 bus lengths to increase the buffer zone between vehicles being fuelled. This design will reduce the likelihood that a spill will envelope more than one vehicle. It may not be possible to economically incorporate this change at Winnipeg. Under existing space constraints, this may have the effect of reducing the number of vehicles within the service area at any one time.

It is essential to ensure that all components within the fuel dispensing system are methanol compatible. Otherwise they will have to be replaced. Non-compatible components are more likely to fail prematurely. Prior to their failure they will probably oxidize (metal) or decompose (plastics/resins), leading to engine operating difficulties and increased vehicle failure rates.

Other changes

Fire detection and fighting equipment must be re-evaluated in light of the fuel change. Given that neat methanol will burn nearly invisibly under ambient light conditions, fire detection equipment should incorporate heat detectors throughout the fuelling area. The heat detectors could be tied to the fuel pump motor. Heat sensitive paint could also be used as an early warning indicator. An overhead sprinkler system should form the principal fire fighting defence. Water is the only fire suppressant that could be safely used within the fuelling facility while transit personnel are present. In addition to a sprinkler system, the service area should be equipped with water hoses and dry chemical type fire extinguishers.

Other modifications would encompass a rework of the ventilation system, electrical equipment, tunnel exit, driveway surface and drainage system.

Ventilation system concerns will centre around maintaining air quality within MWSHA standards. The 8 hour TWA for methanol is 200 ppm while formaldehyde has a TWA limit of 1 ppm. Methanol vapours will be present during engine start-up, idle and fuelling. Unlike formaldehyde, which has a pungent odour and can cause eye, nose and throat irritation at levels between 0.1 to 3 ppm, service personnel may not be so easily alerted to the presence of methanol[30]. The current ventilation system, which is capable of up to 16 air changes per hour appears to be adequate. However, it is recommended that a methanol detector be used to control the building ventilation system. The ventilation rate could then be modulated depending on the ambient methanol concentration. Any personnel present could also be alerted to unsafe ambient conditions and in extreme cases, flammable vapour mixtures.

The fuel pump system should also be interlocked with the ventilation system so that it can only be turned on once the ventilation system has been actuated.

The open flame gas heaters which are used to warm incoming air during the winter months will have to be replaced with a sealed heat exchanger. The heat exchanger should preferably use hot water or steam. These heat exchangers would have to be capable of supplying 2900 KW[31]. A change over to a steam or hot water system will be the single most expensive modification that Winnipeg must perform. As a remote possibility, Transit could possibly purchase high pressure steam from the adjoining VIA Rail maintenance property. VIA Rail has since cut back their operations.

The ventilation system must be sufficient to remove stale air due to exhaust and flammable vapours. The system must be configured such that there are no pockets of "dead air" between the rafters, in work pits or drains, where flammable vapours or exhaust could collect.

The existing ventilation system consists of air intake and exhaust units at both the floor and ceiling level. Although not specifically in need of change, one proposal for a ventilation system, particularly in the case where fuel vapours are heavier than air, involves forcing fresh air in from the ceiling and drawing

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30 Kraft, J. et al - op cit

31 Based on an exterior temperature of -33^{o}C and an interior temperature of 18^{o}C.

air out at floor level to control fuel vapour dispersion. Methanol vapours, although lighter than gasoline are still heavier than air and in an undisturbed environment would settle. This arrangement would draw air towards the grade where it can be collected for exhaust. A ceiling or exhaust hood only needs to be used in locations where the vehicle is normally left idling, such as at the wash rack.

Given that methanol is classified as a flammable liquid, all electrical componentry and connections within the service area will have to conform to explosion proofing provisions laid out in the Manitoba Electrical Code (MEC). Ideally, all electrical equipment that is not absolutely necessary should be removed from the hazardous zone. Items such as the washer motors, cyclone cleaner motors and the motor control panel will have to be upgraded to at least meet Class 1 Division 2 standards. The washer and cyclone electrical control panel will have to be relocated to an adjoining room or be upgraded.

To contain any fuel spillage, the driveway surface will have to be resurfaced and control dikes placed around the fueling area. The surface around each fuelling station should be sloped towards the centre drain grate located in each lane. Alternatively a dike can be placed around the perimeter of the entire fuelling area. Either plan seeks to limit fuel runoff in the event of a large spill. At the same time, the drain trough between the wash area and the fuelling area will have to be isolated. The oil-water separation system should be maintained for drainage from the wash area. To conform with current municipal regulations, all run off from the fuelling area will have to be collected for eventual disposal. It is recommended that a 5000 litre tank be used to collect runoff from the fuelling area. The proposed size is meant to provide a safety margin and minimize the intervals between tank drainings. The tank would have to be vented to the exterior and would function in the same way as a fuel storage tank except that it would collect methanol plus other effluent from the fuelling area. The storage tank installation could have to conform to the Manitoba Clean Environment Act. Leak detection from the storage tank could pose a problem over the long-term. Unlike typical storage tanks where product is metered going into and out of the tank, in this case there is less opportunity for accurate metering. Product input is irregular and the exact volume is unknown. Also, arrangements would have to be made to dispose of the tank contents on a regular basis. Under certain circumstances, it may be feasible to recycle the methanol-water mixture collected in the spill off tank and reintroduce it as windshield washer fluid.

The tunnel entrance/exit, located in the southeast corner of the service area should be isolated from the service area. The present tunnel entrance/exit configuration permits non-service personnel (i.e., drivers and other transit personnel) access to the service area. Based on a direct interpretation of the regulations, no unauthorized persons are permitted in the fuelling area. However, it is also prudent to restrict access and traffic within the service area given that the new fuel is classified as a flammable. The steel railing around the tunnel entrance/exit should be replaced with a fire resistant brick wall. Fire doors would be used to permit direct access to either the storage or service area.

The service bay should also be provided with two emergency eye wash stations and showers.

Changes related to operating procedures are more of an exercise in re-education. Personnel would have to be retrained in the safe handling of methanol and correct response to either a fuel spill, fire or contact with the fuel. The emphasis of the re-education program should be on factual information and not an attempt to intimidate those working near the fuel. To avoid confusion and any possible ill side effects, the fuel must always be referred to as "methanol", **not** "methyl alcohol". Any reference to the term "alcohol" must be avoided. Furthermore, the existing practise of a roving night-time supervisor should be abandoned in the interim. Each facility should be assigned a night time supervisor until employees develop a familiarity with the fuel and changes to operating procedure.

Those directly involved in refuelling would have to be issued protective clothing including gloves and protective eye wear. Although the use of dry-break nozzles should reduce the frequency of fuel spills, as an added safety measure, protective boots and aprons could also be issued.

Table VI-1 below recapitulates the changes required at Winnipeg and their approximate cost. The cost data represents an order of magnitude estimate based on interviews with transit personnel, local equipment suppliers and contractors. The total cost is expected to approach $750K.

The preceding discussion has focussed on the assumption of maintaining the existing service layout and operation. There is limited space available at the Osborne Street property to significantly alter the existing layout. If a new facility were to be constructed from the ground up, the incremental costs attributable to the methanol service area should be comparable to those previously identified for Winnipeg Transit. Much of the aforementioned equipment would not normally be installed in a facility designed for diesel.

There is no advantage to erecting a fuelling facility that is isolated from other service functions (i.e., cleaning, washing and fluid refill). Although this approach would limit personnel and hardware exposed during the refuelling sequence, it would result in an interruption in the service process. Vehicles would have to be shuttled through two discrete areas with a resultant increase in manpower. Additionally, the segregated service or fuelling area would still require much of the same equipment as previously described plus another building.

The methanol powered buses will incorporate methanol compatible components and safety features. To ensure compatibility with the proposed fuelling setup, vehicles will have to be equipped with matching "dry-break" fuel connectors and vapour recovery devices. In addition, the fuel tank fill neck should extend to within 3cm of the tank bottom. This will effectively reduce the volume of fuel vapour that can escape once the filler cap is removed. Such a setup will also reduce splashing and an electrostatic charge build-up in the fuel tank during fill up.

An additional feature worthy of consideration is an ignition interlock placed on the fuel filler door. Once the fuel filler door is opened, the interlock would prevent the vehicle from being restarted until the door is closed. The door would be closed only once fuelling was completed. This feature is highly recommended, not only for methanol, but for diesel powered vehicles too, as a means of reducing drive-aways.

Table VI-1. Summary of Changes to the Service Area

Item	Quantity	Unit Cost	Total Cost	Notes
Fuel Entry & Vapour Recovery Return Line	1	$5,000	$5,000	Buried fuel lines to servicing bay; overhead lines within servicing bay.
Tank Leak Sensor*	12	5,000	60,000	
Fuel Pump	4	3,000	12,000	High capacity 190 lpm.
Dry-Break Vapour Recovery Nozzle	4	2,000	8,000	State-of-the-art Emco-Wheaton methanol compatible.
Breakaway Connector*	4	250	1,000	Methanol compatible fittings.
Flow Meter & Totalizer*	4	5,000	20,000	Fuel measurement and equipped to shut down pump after specified amount of liquid flow.
Ground Strap	4	200	800	Grounding buses directly to fuel dispensing sites & positive ground indicator.
Fuel Storage Tank	2	40,000	80,000	38,000 litre tanks to augment existing in

Table VI-1. Summary of Changes to the Service Area Cont'd

Item	Quantity	Unit Cost	Total Cost	Notes
Fuel Pump Cutoff Switch*	5	500	2,500	One each located at fuel dispensing meter; one within servicing bay but AWAY from dispensing equipment.
Temperature Sensitive Valve	4	500	2,000	Sense high temperatures on rigid piping within service bay; shut down ALL fuel pumps.
Dispenser Flame Sensor	4	5,000	20,000	Flame sensors located at dispensing locations.
Heat Detector	8	500	4,000	Strategically located in servicing bay to sense high heat and wired into fuel pumps; shut off ALL pumps if high heat sensed.
Spill Tank	1	40,000	40,000	Containment of spills - servicing building.
Slope/Dike in Fuel Dispensing Area Floor	1	10,000	10,000	
Overhead Water Sprinkler Systems*	1	5,000	5,000	Augment existing sprinklers located throughout servicing bay with emphasis on fuelling area.

Table VI-1. Summary of Changes to the Service Area Cont'd

Item	Quantity	Unit Cost	Total Cost	Notes
Water Hose and Fire-fighting Nozzle*	4	1,000	4,000	Augmentation of existing systems within service area.
Dry Chemical Fire Extinguisher*	12	200	2,400	Augmentation of existing systems within service area.
Methanol Vapour Sensor	1	40,000	40,000	Tie in with building control system and existing monitors to "trigger" an audible and visual alarm in servicing bay, exterior of servicing bay and operations control centre.
Mechanical & Switchgear Rooms	1	30,000	30,000	Provide fire rated doors and "positive" heated air flow into rooms.
Fire Wall - Stairs	1	15,000	15,000	
Spark-Proof Electric Motors	1	20,000	20,000	Service bay wash brushes, cyclones, overhead door openers, air makeup units.
Replace Overhead Heaters with Hot Water/Steam	1	314,000	314,000	Service bay only.

Table VI-1. Summary of Changes to the Service Area Cont'd

Item	Quantity	Unit Cost	Total Cost	Notes
Explosion-proof Lighting	1	20,000	20,000	Applicable to service bay; to replace fluorescent fixtures.
Eye Wash Station	2	1,000	2,000	Located within servicing bay area.
Personal Shower	2	2,000	4,000	Located within servicing bay area.
No Smoking Campaign	1	5,000	5,000	Signage for entire complex, literature, promotional items.
Training (persons)	20	60	1,200	Training of servicing staff (including supervisors).
Protective Footwear	50	50	2,500	For fuel dispensing personnel only.
Protective Gloves	50	25	1,250	For fuel dispensing personnel only.
Protective Aprons	50	100	5,000	For fuel dispensing personnel only.
Protective Glasses	50	10	500	For fuel dispensing personnel only.
Total Physical Plant			$737,150	

* Also applicable in comparable new diesel fuel installation.

C. VEHICLE STORAGE

The most probable source of risk, as identified in Chapter IV, appears due to small scale fuel leaks or drips and a buildup of exhaust emissions during dispatch. The risk management plan should focus on mitigating the risk posed by these two events. Most of the changes within the storage area would center around procedural changes and some minor changes to the ventilation system. Overall, the concept of methanol vehicle storage should not pose a significant barrier. Gasoline vehicles are currently housed in storage bay 1.

Air quality within the storage areas has already been identified as a concern by Winnipeg Transit. Winnipeg is in the process of upgrading its ventilation system. Air quality complaints arise during the morning and afternoon dispatch when buses are left idling prior to their dispatch. Engine idle time currently varies between 2 minutes in summer and 10 minutes in winter. Differences in idle time are attributable to, among other things, vehicle warm-up. Drivers are leaving their vehicles idle indoors until the heating system is warmed up. To reduce interior emissions levels and the burden on the ventilation system, operating procedures should be re-examined with respect to restricting vehicle idle time, particularly if the vehicle is parked indoors. An engine will also warm up faster if it is under load. A reduction in idle time will also translate into fuel savings and hence, reduced operating costs.

The ventilation system within the storage area must be isolated from the service area. The air change rate within the service area can be varied depending on the time of day. The ventilation (air change) rate will be greatest during dispatch periods, but can be trimmed back during the day when activity is at a low and most vehicles are out on the road. As in the service area, it is recommended that the ventilation system be controlled by a gas detector set to monitor methanol vapours in addition to carbon monoxide (CO) or nitrogen oxides (NO_X).

To replace the overhead natural gas air heaters with either a steam or hot water system could easily become the single most costly item. It becomes debatable as to whether these heaters must be replaced. Identical style heaters are used in B section, which houses gasoline powered (flammable liquid) vehicles. Some may question the different treatment accorded methanol.

All electricals, particularly those below and just above the grade, will have to be inspected to ensure compliance with at least Class 1, Division 2 standards of the Manitoba Electrical Code. It may also be necessary to upgrade or relocate the exhaust fan switches.

Smoking was previously identified as posing a "high" relative risk (with regards to potential ignition sources) given the dense packing of the buses into queues and the tendency of vehicles to drip fluids. It is also the only ignition source that can be easily eliminated from the storage area. Electrical equipment within the storage area can be upgraded but not eliminated. Although there is no specific provision to prohibit smoking in this area, as a matter of safety, it should be banned or alternatively restricted to designated areas. An effective ban on smoking will still not eliminate the problem of fluid drips. Rather it will eliminate one potential ignition source. A regular inspection and maintenance program must incorporate a fuel system leak check. Drivers should also be encouraged to report all fluid leaks.

The transit facility should attempt to seek a waiver from the City of Winnipeg entitling it to maintain the existing oil-water separator and sewer connections. Based on fluids recovered from the oil-water separator, drips could possibly account for at least 0.6 litres per day from the entire storage area (This includes both diesel fuel and oil). Most methanol fuel drips are expected to be relatively minor in size. Small fuel spills would be best handled by applying a desiccant and disposing of the desiccant and methanol. What remains of the fuel leak would be diluted with water when the parking apron is washed. If flushed into the sewer system, the methanol concentration is expected to be innocuous. A large scale fuel release, such as a traumatic fuel tank failure, is rated as a relatively low probability. In the event of a large scale spill, the sprinkler system or fire hoses could be used to dilute the spill and flush it away.

Table VI-2 identifies the necessary changes required in the storage area.

The basic cost to modify the storage bay is expected to approach $106,000. This includes training, augmenting existing fire fighting equipment and electrical installation, and installation of a methanol vapour sensor. It is uncertain whether the existing heating system will have to be replaced and a spill tank installed. The inclusion of these two items would boost the total modification costs to nearly $650,000.

Table VI-2. Summary of Changes to the Vehicle Storage Area

Item	Quantity	Unit Cost	Total Cost	Notes
Spill Tank	1	$40,000	$40,000	Containment of spills if required.
Water Hose & Fire-fighting Nozzle	4	1,000	4,000	Augmentation of existing systems.
Dry Chemical Fire Extinguisher	20	200	4,000	Augmentation of existing systems.
Methanol Vapour Sensor	1	40,000	40,000	Tie in with building ventilation control system to "trigger" an audible and visual (if required) alarm in servicing bay, exterior of servicing bay and operations control centre.
Isolate Exhaust Fan Switches and Make Up Air Controls	1	40,000	40,000	Relocate switches or upgrade electricals.
Replace Overhead Heaters with Hot Water/Steam	1	500,000	500,000	Augment boiler system and add piping to cover the storage area.
Training (persons)	300	60	18,000	Training of all drivers (including supervisors).
Total Physical Plant			$646,000	

D. MAINTENANCE AREA

The greatest risk from methanol buses within the maintenance area arises due to small fuel spills or leaks, and exhaust emissions. The most probable source of fuel spillage will arise during fuel filter changeouts. Many of the facets of the risk management plan for the storage area are equally applicable to the maintenance shop. Changes within the maintenance area include changes to current operating procedures and a reorganization of the work areas.

Fuel system maintenance is currently performed throughout the garage. One can not enjoy that freedom with methanol given its properties. It will become necessary to restrict or control activities that are performed around the fuel system. One approach is to reduce the risk around vehicles brought in for maintenance. While it will not be possible to eliminate fuel spillage nor ignition sources within the maintenance area, it is possible to restrict or contain all vehicle fuel system related maintenance to one particular area and eliminate open flames or sparks in that area. At least two work slots, away from any work area where sparks or open flames are likely to be generated, should be set aside for fuel system related work. Alternatively, if space permits, a wall or partition, extending from the floor level to at least 3m in height could be used to isolate the fuel workshop area from ignition sources in adjacent bays. Smoking would also be prohibited within this area. Additionally, any repair work involving open flame, spark or ignition sources near the fuel system would be prohibited until the fuel system was drained and flushed.

Analogeous to the situation within the storage area, a holding tank may be required to collect all effluent that enters the sewage system. If fuel system repairs are limited to a controlled area, an isolated drainage system could be installed in the fuel repair area to collect all spills and route them to a holding tank. The existing oil-water separator connections would be maintained in the remaining areas of the shop. Until the question about methanol releases into the sewage system is resolved, holding tanks may be a necessary component of the transit facility.

Fuel removed from a vehicle fuel system during routine maintenance should be collected in specially designated containers. This action is aimed at preventing fuel being drained onto the work area and eventually entering the drain system. Moreover, this fuel could then be recycled back into the vehicle fuel system thus controlling fuel costs.

No specific recommendations are made with regards to changing the ventilation system. The current practise of employing exhaust pipe hoses appears to be an effective means to vent exhaust emissions outside.

Employees in the maintenance area would have to be briefed on fuel safety and emergency procedures.

Total costs within the maintenance area are expected to amount to approximately $65,000. Table VI-3 outlines the changes and their anticipated costs.

Table VI-3. Summary of Changes to the Maintenance Area

Item	Quantity	Unit Cost	Total Cost	Notes
Training	180	$60	$10,800	Training all maintenance staff and supervisors.
Eye Wash Station	2	$1,000	2,000	Located within maintenance area.
Personal	2	$2,000	4,000	Located within maintenance area.
Shower Methanol Spill Tank	1	40,000	40,000	Spill containment from fuel system maintenance area.
Fire Wall	1	6,000	6,000	Around fuel system work station in maintenance area.
Total Physical Plant			$62,800	

E. RISK MANAGEMENT SUMMARY

The preceding sections outlined a series of both mandatory and recommended actions that should be pursued by Winnipeg Transit if it is to convert its Osborne facility to methanol fuel operations. The proposals are aimed at satisfying regulatory requirements and concerns expressed by the fleet based on the risk analysis of Chapter IV and fuel properties discussed in Chapter III. Completion of the aforementioned proposals described in this chapter will not necessarily assure final acceptance of the methanol fuel transit facility. There is still a great deal of uncertainty as to what constitutes the minimum design acceptable to regulatory authorities.

There is still much uncertainty as to what exact combination of design features will produce an overall facility design that provides an equal measure of risk as that of a diesel fuel facility. Many of the chemical properties of methanol, as pointed out in Chapter III, are entirely different than those of diesel. While one must attempt to avoid the occurance of a hazard precursor, a fuel spill for example, the resulting hazard assessment

(environment, health and fire or explosion) will be entirely different with either fuel. For example, methanol is hygroscopic and can escape into the sewage system if left unchecked. In the case of a fire, methanol would burn with a lower flame temperature hence radiating less heat, yet within a burning pool one would expect the same degree of damage as with diesel fuel. In any risk management plan, one must balance these factors.

The major modifications that are proposed for Winnipeg Transit include sealed heating systems; explosion proof electrical switches, motors, and lights; and spill catchment tanks. The total capital costs for the proposed changes at Winnipeg are expected to range between $900,000 and $1.5 million. Part of the variability in cost is due to the uncertainty with respect to the treatment of effluent from the storage and maintenance area and the status of the air heating systems within the storage area. Many of the proposals are equally applicable to a new facility but would not necessarily be as costly. There will also be legal and engineering fees associated with the design. Given that there are no methanol fuel transit facilities, these fees are expected to be significant. The transit facility will likely have to justify their design to licensing authorities.

Of all three facets of indoor transit operation examined, the service operation, or more specifically the refuelling operation is likely to be the most critically examined by all parties. Modifications to the indoor service area at Winnipeg Transit are expected to approach $750,000. There does not appear to be any significant advantage gained by isolating the fuelling activity from all other service activities.

VII CONCLUSIONS AND RECOMMENDATIONS

There is no unique measure that permits one to absolutely rate and evaluate one fuel compared to another. Different fuels, because of their individual properties, offer specific advantages. Compared with diesel, methanol offers reduced particulate and nitrogen oxide emissions. However, its often cited drawbacks, when compared with diesel, include the fact that the fuel burns with a nearly invisible flame under daylight conditions and it is classified as a flammable fuel. Hence the more stringent handling requirements.

There is no regulatory barrier limiting the introduction of methanol as a motor vehicle fuel or specific restriction on indoor fuelling with methanol. There does not appear to be any specific regulatory restriction regarding the indoor storage and maintenance of methanol powered vehicles. The current body of regulations governing fuel transfers has evolved on the premise of gasoline (rated as a flammable liquid) and diesel (rated as combustible liquid) being the primary transportation fuels. All indicators are that methanol would be treated identically to gasoline. However, compared to gasoline, methanol exhibits some different characteristics: it can be rendered non-flammable and non-toxic when diluted with water; and methanol vapour will more easily diffuse. These differences will have to be addressed by regulatory authorities if methanol is to make successful inroads as a transportation fuel.

There are no existing indoor methanol fuelling facilities. Therefore, there is no bench mark or standard from which to evaluate any proposed design. All proposed designs must be measured with respect to the existing regulations. The final decision regarding any proposed design rests with regulatory authorities. At the same time, the design must satisfy any concerns raised by the intended users, their insurers and the surrounding community. Many of the existing questions about the best facility design will be answered through an evolutionary design process.

Small fuel drips or leaks and an exhaust emissions buildup were identified as the most probable hazard precursors on transit properties today. Hazard precursors can lead to one or more of three possible outcomes: fire or explosion; impairment to health; and damage to the environment. Assuming the frequency of hazard precursors remains constant, irrespective of a

change to methanol fuel, it is possible to address those concerns through a series of hardware and procedural changes. These changes would comprise part of a risk management plan designed to mitigate the risk associated with a change in fuel type.

The total costs required to convert the Osborne Street Transit Base of Winnipeg Transit would range between $900,000 to $1.5 million. This estimate is based on improvements to the existing property in order to meet what are perceived to be the minimum standards required to satisfy regulatory authorities and the transit operator. The range in costs is due to uncertainty concerning the exact interpretation of the regulations concerning methanol fuel particularly the need for separate catchment spill tanks. The bulk of the required work will centre around the vehicle service area. The service area design, and in particular, the fuel transfer activity would be the most closely scrutinized. The estimated cost to modify the service area was nearly $750,000. These costs were estimated exclusive of any costs associated with the purchase of methanol buses. In reality, the actual conversion over to methanol fuel would entail other expenses including engineering and legal fees plus the cost of interruptions during the conversion process.

There is no definitive "final design" or approach to all methanol fuel transit facilities. The proposals contained herein are applicable to other facilities contemplating conversion to methanol vehicle operation as well as new facilities being erected. However, the design would have to be customized depending on transit criteria and concerns expressed by local regulatory authorities.

Before completing the design of indoor operations with methanol, it is recommended that a dialogue be opened between the transit industry, regulatory authorities and other interested stake holders. The final design must satisfy all parties.

APPENDIX 1

METHANOL RESISTANT POLYMERS

APPENDIX 1

List of Methanol Resistant Polymers*
Polyethylene Polpropylene Acetates Fluorinated elastomers
Non Methanol Resistant Polymers*
Natural rubber Epoxy resins Polyurethanes Fibreglass/polyester

* These are only partial listings for general information purposes. The reader is urged to contact a local distributor or supplier for a more through listing and product specification.

APPENDIX 2

SUMMARY OF MANITOBA REGULATIONS APPLICABLE TO A METHANOL FUELLED TRANSIT FLEET

APPENDIX 2

SUMMARY OF MANITOBA REGULATIONS APPLICABLE TO A METHANOL FUELLED TRANSIT FLEET

(N.B. THIS TREATMENT IS APPLICABLE TO THE TRANSIT FACILITY INFRASTRUCTURE)

REGULATIONS GOVERNING THE STORAGE & DISPENSING OF METHANOL

Activity/Subject Descrip.	**Regulation I.D.**
A - Electrical Equipment	MEC Chapters 12,18 & 20
B - Structural	
Fire Walls	MBC Chapter 3
C - Fire Prevention And Protection	
Fire Extinguishers	MFC 4.1.5.2
	4.1.5.3
Open Flames	4.1.5.4
Smoking	4.1.5.5
	2.4.2.3
Removal Of Combustibles	4.1.5.6
Fire Safety Plan	4.1.5.7
Access Paths	4.1.5.8
Welding And Cutting	4.1.5.9
D - Drainage And Waste Disposal	
Spillage	MFC 4.1.6.1
Drainage Location	4.1.6.2

E - Ventilation	MFC 4.1.7.1 MBC 9.33.14 6.22.2 LRM W210
F - Fuel Handling	
Storage	MFC 4.1.8.1
Grounding	4.1.8.2
Transfers	4.1.8.3
Dispensing Into Fuel Tanks	4.1.8.4
G - Liquid Spills And Leaks	
Preventive Procedures	MFC 4.1.9.1
H - Storage Tanks	MFC 4.3.8 ULC S603.1
I - M&O Procedures	MFC 4.1.9
J - Piping And Pumping Systems	MFC 4.4.1
K - Shut Off Valves	MFC 4.4.8.2 ULC C842
L - Sprinklers	MBC 3.2.2

M -Waste Disposal

MFC 4.1.6

Legend:

MFC:	Manitoba Fire Code
MEC:	Manitoba Electrical Code
MBC:	Manitoba Building Code
ULC:	Underwriters Laboratory of Canada

LIST OF APPLICABLE CODES AND ACTS

National Fire Code Of Canada 1985, Associate Committee on the National Fire Code of Canada, National research Council of Canada, Ottawa, Ontario, 1985.

National Building Code Of Canada 1985, Associate Committee on the National Building Code, National Research Council of Canada, 1985.

Canadian Electrical Code Part 1, Safety Standards For Electrical Installations, Canadian Standards Association, Rexdale, Ontario, 1986.

Manitoba Electrical Code Fourth Edition, Manitoba Hydro, Winnipeg, Manitoba, 1987.

Regulations Respecting Control of Exposure to Biological or Chemical Agents - Made Under the Occupational Health and Safety Act, Ontario Ministry of Labour, Occupational Health and Safety Division, 1980.

Gasoline Handling Act, Government of Ontario, Ministry of the Attorney General, Queens Printer of Ontario, 1989.

Energy Act, Government of Ontario, Ministry of The Attorney General, Queens Printer of Ontario, 1989.

APPENDIX 3

PERMISSIBLE EXPOSURE FOR VARIOUS AIR CONTAMINANTS

APPENDIX 3

PERMISSIBLE EXPOSURE FOR VARIOUS AIR CONTAMINANTS

Agent	TWA[1]		STEL[2]	
	Manitoba ppm	Ontario ppm	Manitoba ppm	Ontario ppm
Acetaldehyde	100	100	150	150
Acetone	750	750	1,000	1,000
Acrolein	0.1	0.1	0.3	0.3
Carbon Black	-	-	-	-
Carbon Dioxide	5,000	5,000	30,000	30,000
Carbon Monoxide	50	35	400	400
Formaldehyde[3]	*	1	*	2
Methanol	100	200	200	250
Nitrogen Dioxide	3	3	5	5
Nitric Oxide	25	25	-	-

Note:

1. TWA - Time-Weighted Average Exposure
2. STEL - Short Term Exposure Limit
3. Manitoba recognizes that formaldehyde is a suspected carcinogen. The limits should be as low as practical.

Reference:

Manitoba: Exposure values are based on the American Conference of Government Industrial Hygenists (87-87) (ACGIH).

Ontario: Occupational Health and Safety Act. Revised Statutes of Ontario, 1980. Chapter 321 Ontario Regulation 654/86. Amended by Ontario Reg. 707/86 and 339/87.